MEDICAL ENTOMOLOGY

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Ever yours sincerely

Geo. H. F. Nuttall.

(M.D. 1884, LL.D. Hon. Causa 1924, U.C.)

MEDICAL ENTOMOLOGY

with special reference to the health and well-being of man and animals

by WILLIAM B. HERMS

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3RD EDITION

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In acknowledgment
of his inspirational leadership
in the field of Medical Entomology
the author gratefully dedicates
this book to the memory of

GEORGE H. F. NUTTALL, M.D., Sc.D., LL.D., F.R.S.
Late Quick Professor of Biology, Cambridge University

PREFACE TO THE THIRD EDITION

The present edition of *Medical Entomology* is in fact a complete revision of *Medical and Veterinary Entomology* which has appeared in two previous editions. Since the appearance of the second edition in 1923 great strides have been made in the study of arthropods as vectors of diseases of both man and beast, necessitating a complete rewriting of much of the matter appearing in the previous editions. During the past few years much emphasis has been placed upon the public health in its many ramifications, not the least important of which is the field of parasitology, particularly medical entomology, a viewpoint which the author expressed in the first edition.

Fully recognizing the importance of knowledge of animal diseases in the field of public health, but acceding to the desire for brevity, the title of this work has been shortened. The public health aspects have been measurably strengthened and the experimental method is stressed. Numerous new illustrations have been used to replace old ones and many new citations are included.

The author gratefully acknowledges the very generous assistance given by the members of his staff and assistants in the preparation of this edition. Particular mention must be made of the assistance given by the following: Mr. D. E. Howell, Mr. Thomas H. G. Aitken, Dr. Florence M. Frost, Dr. M. A. Stewart, Dr. S. B. Freeborn, Dr. C. M. Wheeler, Mr. H. F. Gray, Dr. E. Gorton Linsley, and Dr. Robert L. Usinger. The author is indebted to Miss Elizabeth C. Keal for assistance in the preparation of the manuscript. To the artist employed under the United States Works Progress Administration credit is due for assistance in the preparation of several illustrations.

The author is under obligation to Professor D. Keilin, Director of the Molteno Institute of Biology and Parasitology, University of Cambridge, for assistance in securing the excellent photograph of Professor George H. F. Nuttall in whose memory this work is dedicated.

W. B. H.

Berkeley, California
October, 1938.

PREFACE TO THE FIRST EDITION

Much of the matter contained in the following pages was prepared for the press more than six years ago, but owing to the rapid advances made in the field of parasitology, particularly concerning insects, the writer has withheld it until this time, when, after considerable revision and addition, it has seemed expedient to publish the same. The manuscript has been in almost constant use for a period of six years in teaching classes in parasitology, both in the University of California and in the San Francisco Veterinary College. It has been the aim to include herewith a large part of the writer's original work, some of which has until now remained unpublished, as well as the published observations of many other investigators in this field, all of which has gone to build up the foundation of the new science of *Medical Entomology*.

This book is not intended to be a comprehensive treatise touching all the investigations in the field of medical entomology, but rather an attempt to systematize the subject and to assist in securing for it a place among the applied biological sciences. However, a discussion is included of all of the more important diseases and irritations of man and of the domesticated animals in which insects and arachnids are concerned, either as carriers or as causative organisms.

Owing to the immense literature on insects as relating to disease, much of which is widely scattered, the student in this field must spend considerable time in searching for the desired information and, what is more important, the information is not readily accessible to the physician, the veterinarian, the health officer and the sanitarian. It is therefore to be hoped that this book will not only prove useful as a text, but also as a handbook for all individuals who are professionally interested in the health and well-being of man and beast, as affected by insects and arachnids.

In the second place detailed accounts of experiments are included here and there, so that the investigator might employ the methods described in either the repetition of the work or in carrying on further investigations along the lines suggested.

Although many special papers have been consulted in the preparation of this work, a bibliography is not included herewith, inasmuch as this information is obtainable in much more complete form in the bibliographical works of other writers. Reference to special papers is usually

made in footnote form, but where certain facts have long been accepted as common knowledge, reference is ordinarily omitted.

Sources from which assistance has been drawn are too numerous to enumerate adequately, but to all who have contributed toward the preparation of this work I wish to express my sincere appreciation and thanks, but most particularly to my advanced students in parasitology, who have contributed much valuable data, and to my colleagues, Professor C. W. Woodworth, Dr. Edwin C. Van Dyke, Dr. W. A. Sawyer, and Dr. S. B. Freeborn, and to my wife, Lillie M. Herms, for generous coöperation and kindly criticism.

Unless otherwise credited the illustrations are from photographs and drawings made by the author and various assistants. Thanks are due particularly to Dr. William Colby Rucker for the use of flea drawings, to Professor Herbert Osborn for permission to reproduce certain drawings of biting and sucking lice, to Dr. Bruce Mayne for photographs of *Tabanas striatus,* and stomachs of infected *Anopheles* mosquitoes, to Professor J. S. Hine for photographs of certain other tabanids, and to Mr. W. C. Matthews, scientific illustrator, for valuable assistance in the preparation of many of the figures.

W. B. H.

Berkeley, California.

PREFACE TO THE SECOND EDITION

The author owes a debt of gratitude to the many readers of the first edition for the cordial reception accorded to it, a reception which makes possible this new edition.

The rapid growth of literature dealing with insects and related organisms, as they affect the public health and animal industry, has made it necessary to rewrite most of the subject matter in order to keep it largely within its original limits. An historical account of the development of Medical Entomology has been added and many of the chapters have been enriched by the experience of the author as a Sanitary Officer in the United States Army during the late war. Many new illustrations have been added and a few old ones have been replaced. Those who have used the first edition will find the new edition practically a new book, and if the second edition of *Medical and Veterinary Entomology* receives the same wide use and general approval as the first edition, the author will feel amply repaid for the arduous labor involved in its preparation.

W. B. H.

Berkeley, California.

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CHAPTER I

INTRODUCTION

Historical.—In the King James Version of the Old Testament (Exodus 8, 24) we read, "and there came a grievous swarm of flies into the house of Pharaoh, and into his servants' houses, and into all the land of Egypt: the land was corrupted by reason of the swarm of flies." The Douay Version reads, "and the land was corrupted by this kind of flies." Whether the term "flies" as used in this passage is coextensive with its modern use may be questioned, but it is interesting to contemplate its possible significance. As early as 1577 Mercurialis [1] expressed the belief that flies carried the virus of plague from those ill or dead of plague to the food of the well. Although we now know that this is not the usual mode of plague transmission, the principal rôle that flies play as vectors of disease was correctly interpreted, i.e., they are conveyors of infection to food.

In 1587 Gabriel Soares de Souza [2] stated that flies suck poisons from sores (*Framboesia tropica*) and leave them in abrasions on healthy individuals, thus infecting many persons. In 1769 Edward Bancroft [3] advanced a similar theory, but it was not until 1907 that Castellani [4] demonstrated experimentally that flies do transmit *Treponema pertenue* Castellani, the causal agent. The housefly as a real menace to health was, however, hardly appreciated until 1898 during the Spanish American War when Veeder [5] wrote:

> "I have made cultures of bacteria from fly tracks and from the excrement of flies and there seems to be not the slightest difficulty in so doing. Indeed the evidence of every sort is so clear that I have reached the conclusion that the [illegible]

Although popular beliefs in parts of Europe, Asia and Africa had for many years connected mosquitoes with various tropical fevers, no well formulated ideas were advanced until 1848 when Josiah Nott [6] of New Orleans published his belief that mosquitoes gave rise to both malaria and yellow fever. In 1854 Daniel Beauperthuy,[7] a French physician in the West Indies, formulated an excellent theory that mosquitoes were responsible for the transmission of yellow fever, believing, however, that

[1] All references are to the Bibliography at the end of each chapter.

the disease factor was carried from decomposing matter and introduced into the human body by the insect.

While considerable was known by early naturalists and physicians concerning the larger intestinal parasites, such as roundworms and tapeworms, little information relating to microörganisms was available until after the development of the microscope by Anton van Leeuwenhoek [8] (1695). The discovery that his "material contained many tiny animals which moved about in a most amusing fashion; the largest of these showed the liveliest and most active motion, moving through the water or saliva as a fish of prey darts through the sea," led to the study of hitherto invisible organisms and eventually to the formulation of the "germ theory" by Pasteur [9] in 1877.

Although according to Howard [10] no standard medical treatise mentioned any specific insect-borne disease prior to 1871, Raimbert [11] showed in 1869 by experiment (inoculation of proboscides, wings, etc., of non-biting muscids into guinea pigs) that anthrax (*Bacillus anthracis* Cohn) could be disseminated by flies, which was believed to be the case as early as 1776 by Montfils.[12] The first discovery, however, of primary importance in the field of medical entomology was made in 1878 when Patrick Manson,[13] working in China, observed the development of *Wuchereria* (=*Filaria*) *bancrofti* (Cobbold) in the body of a mosquito, *Culex fatigans* Wied. (*Culex quinquefasciatus* Say) and eventually together with Bancroft, Low and others he proved the mosquito to be the intermediary host and vector of the causative organism of filariasis.

The discovery by C. L. A. Laveran [14] in 1880 of the causative organism of malaria (*Plasmodium malariae*) as an inhabitant of the red blood cells of man, marks an epoch in protozoölogy. Taking rank with Laveran's discovery of the malaria parasite is the discovery by Theobald Smith in 1889 (Smith and Kilbourne, 1893 [15]) of the causative organism (*Babesia bigemina*) of Texas cattle fever, also a red-blood-corpuscle-inhabiting protozoön. Associated with Smith in the investigation of the disease was F. L. Kilbourne, and together in 1893 they made the second great fundamental discovery in the field of medical entomology, namely that the cattle tick, *Boöphilus annulatus* (Say) (*B. bovis* Riley), is the necessary intermediary host of the causal agent of the disease. Thus combined with Manson's discovery concerning mosquitoes and filariasis, a new basis for the control and prevention of disease in both man and domestic animals was established.

In quick succession there followed a series of famous discoveries. In 1895 Bruce [16] investigated Nagana, the fatal tsetse-fly disease of Africa (Zululand) and established the fact that the infection is conveyed from animal to animal through the agency of *Glossina morsitans* Westwood.

In 1897 Ronald Ross [17] announced that he had found the zygotes of

the malaria parasite in two "dapple-wingled mosquitoes" (Anophelines) which had been bred from the larva, and fed on a case containing crescents. In the discovery that mosquitoes carry malaria there are linked the names of Ross, Manson,[18] MacCallum,[19] Bastianelli, Bignami, Grassi,[20] Koch, R.,[21] Sambon and Low,[22] the last two in 1900 having demonstrated beyond a doubt the fact of transmission.

One of the world's outstanding achievements in the field of experimental medicine is that of the United States Army Yellow Fever Commission, consisting of Reed,[23] Carrol, Lazear and Agramonte, which in 1900 on the island of Cuba proved beyond doubt that yellow fever is carried by a mosquito, *Aedes aegypti* (Linn.) [then known as *Culex fasciatus* Fabr. and later as *Stegomyia fasciata* (Fabr.)]. Carlos Finlay,[24] a Cuban physician, had as early as 1880 propounded the theory and conducted experiments in an attempt to prove it, hence he, too, amply deserves recognition and great praise.

These two discoveries concerning malaria and yellow fever gave great impetus to the subject of mosquito control, although L. O. Howard had already demonstrated the value of kerosene in his experiments in the Catskill Mountains in 1892. Howard's pioneer book entitled "Mosquitoes: how they live; how they carry disease; how they are classified; how they may be destroyed" appeared in 1901.

Like the study of malaria but for a different reason little advance was made in knowledge concerning the transmission of yellow fever for almost a third of a century and in both instances the complete solution of the problem of control apparently at hand, that is, simply mosquito control, seemed to have been reached with the discoveries above mentioned. However, malaria is now again referred to as a mysterious disease. Hackett[25] (1937) in his treatise on "Malaria in Europe" states, "under close examination malaria became only more intricate and impenetrable, more protean in its character, more diverse in its local manifestations." The expression "anophelism without malaria" came into use, and malariologists became more interested, as Hackett points out, in the anophelines which did not transmit malaria than in those that did. The discovery by Falleroni[26] in 1926 that *Anopheles maculipennis* Meigen, an important vector of malaria, was in reality separable into races based on differences in the egg pattern, led Hackett, Martini and Missiroli[27] (1932) to the discovery that the races of this species differ markedly in their relation to malaria, thus opening new vistas of research and plunging what appeared to be a clear-cut situation in 1898 once more into chaos.

Thus also what appeared to be a well solved problem of yellow fever control through the control of *Aedes aegypti* (Linn.) was again completely thrown open for further investigation by the discoveries of Stokes,

Bauer and Hudson [28] in 1927 that experimental animals (monkeys) can be infected with yellow fever. Now because of the availability of experimental animals instead of one species of mosquito more than a dozen species are known to have the ability to transmit the disease from monkey to monkey by the bite.

In 1932 there was first observed in the Valle de Chanaan, Espirito Santo, Brazil, a type of yellow fever designated as jungle yellow fever (Soper, 1936)[29] differing from the known type transmitted usually by *Aedes aegypti* (*Linn.*) in that it occurs under conditions suggesting that infection takes place away from houses, that man may not be an essential factor in the continuity of infection, indeed "man may be but an accident in the course of an epizoötic in the lower animals, or it may even be due to the persistence of the virus in invertebrate vectors for long periods of time."

In 1898 Simond [30] succeeded in transmitting plague from a sick rat to a healthy rat through the agency of infected fleas. This discovery was at first discredited, but the experiments were successfully repeated by Verjbitski [31] in 1903 and Liston [32] in 1904.

The designation sylvatic (selvatic) plague has come into use particularly since 1928 (Ricardo Jorge, Rongeurs et Puce, Masson et Cie, Paris) to specify plague of wild rodents in which fleas play an important rôle as invertebrate reservoirs as well as vectors.

At this juncture of our historical review of the subject it is appropriate to call attention to the first comprehensive treatise dealing with arthropods as carriers of disease, namely the work of the late Professor George H. F. Nuttall (see frontispiece), published in 1899 in the Johns Hopkins Hospital Reports, vol. viii, nos. 1–2, and entitled, "On the rôle of insects, arachnids and myriapods as carriers in the spread of bacterial and parasitic diseases of man and animals. A critical and historical study." Every student of medical entomology should be familiar with this publication. The following quotation from that work is significant:

> "Whilst hygienists have given much attention to the study of pathogenic organisms in air, water, soil and food, their behavior under different chemical and physical conditions, as also to the possibility of their direct or indirect transmission from diseased to healthy individuals; relatively little attention has been paid to one of the means by which infectious diseases are spread, to the rôle played especially by insects, which may serve either as carriers or intermediary hosts of disease-agents. The most thorough work in this direction has been done by parasitologists. Very few of the works on hygiene even mention the rôle of insects as carriers of infection, and those that do, generally speak vaguely on the subject."

Nuttall deserves to be called the father of Medical Entomology and accordingly the author gratefully dedicates this work to his memory.

In 1901 Forde[33] observed certain parasites in the blood of persons suffering from Gambian sleeping sickness, which Dutton[34] recognized as trypanosomes and named *Tryponosoma gambiense*, and in 1903 Bruce and Nabarro[35] showed that *Glossino polpalis* (Robineau-Desvoidy) was tho carrier, thus adding another tsetse-fly disease to the list. Stephens and Fantham[36] in 1910 described *Tryponosomo rhodesiense* as the causative organism of Rhodesian sleeping sickness and Kinghorn and Yorke[37] in 1912 proved *Glossina morsitans* Westwood to be the responsible vector.

Dengue or breakbone fever, a widely distributed disease particularly of warm climates though frequently occurring elsewhere, was found to be a mosquito-borne disease by Graham[38] while working in Syria in 1902. Graham and later Ashburn and Craig[39] showed that several species of mosquitoes, such as *Culex fatigons* Wied. and *Aedes aegypti* (Linn.), are able to transmit the disease. A very closely related disease is pappataci fever, also known as three-day fever, or sand fly fever, of which *Phlebotomus popatasii* Scopoli has been shown to be the vector by Doerr, Franz and Taussig[40] in 1909.

In 1903, fowl spirochaetosis caused by *Spirochaeto gollinorum* Blanchard was proved to be tick borne by Marchoux and Salimbeni,[41] who showed *Argos persicus* (Oken), the common fowl tick, to be a vector. Another tick-borne disease came to light when Dutton and Todd[42] and Ross and Milne[43] in 1904 discovered that African relapsing fever is carried by the tick, *Ornithodoros moubato* (Murray), the causative organism being *Spirochaeto recurrentis* Lebert (*Spirochaeta duttoni* Novy and Knapp). Furthermore, in 1906 Ricketts,[44] working in Montana (U.S.A.), proved conclusively that a tick which he believed to be *Dermocentor occidentalis* Neum., but now known to have been *Dermacentor ondersoni* Stiles (*Dermacentor venustus* Banks), is the principal vector of Rocky Mountain spotted fever of which Wolbach[45] (1919) considered *Rickettsia* (=*Dermacentroxenus*) *rickettsi* (Wolbach) to be the causative organism.

Although lice have for centuries been associated with filth and disease, apparently little thought was given these insects as possible carriers of infection, even though Melnikoff[46] in 1869 had shown that the biting dog louse, *Trichodectes canis* DeGeer, was an intermediary host of the double-pored tapeworm, *Dipylidium caninum* (Linn.), which occasionally occurs in humans. In 1879 Aubert,[47] according to Nuttall, considered that pediculi caused impetigo, prurigo, pityriasis, etc., and in experiments carried out by Dewèvre[48] in 1892 lice were shown to carry the specific microörganisms on their front legs and infection was thus transmitted to healthy persons. Furthermore, Flügge[49] in 1891 and Tictin[50] in 1897 both supposed that disease might be carried by vermin

and conducted experiments with bedbugs. In 1907 Mackie [51] working in India found that Asiatic relapsing fever was transmitted by the body louse, *Pediculus humanus* Linn., in whose body the causative organism, *Spirochaeta recurrentis* Lebert (*S. carteri* Manson), multiplies.

It was not, however, until 1909 that Nicolle, Comte and Conseil [52] working in Tunis, and Ricketts and Wilder [53] in 1910 working independently in Mexico proved experimentally that the body louse (*Pediculus humanus* Linn.) was a carrier of typhus fever, the causative organism of which, *Rickettsia prowazeki*, was described and named by Da Rocha-Lima [54] in 1916.

Members of the insect family Reduviidae (conenose bugs or kissing bugs) have been long known for their fierce bites and bloodthirstiness, but it was apparently not until 1909 that insects of this group were experimentally proved to be disease carriers! In that year Chagas,[55] who had already described the causative organism, *Trypanosoma cruzi*, of Chagas' disease, also known as Brazilian trypanosomiasis or parasitic thyroiditis, demonstrated that this disease was carried by the conenose bug *Mestor megistus* (Burm.) [*Triatoma megista* (Burm.) =*Panstrongylus megistus* (Burm.)]. Kofoid and Donat [56] 1933 have shown that the trypanosome of the conenose bug *Triatoma protracta* (Uhler) in California is identical with that found in *Mestor megistus* (Burm.).

Flies of the family Tabanidae (horseflies, gadflies, earflies, deer flies, etc.) as already observed were looked upon with suspicion as early as 1776, but apparently no satisfactory evidence was forthcoming until 1913, when Mitzmain [57] (Mayne) working in the Philippine Islands demonstrated the transmission of surra of the carabao through the agency of *Tabanus striatus* Fabr. which he regards as the principal carrier. Strong evidence against tabanid flies of the genus *Chrysops* as intermediary hosts of *Loa* (=*Filaria*) *loa* (Cobbold) as advanced by Leiper [58] also in 1913.

Bloodsucking gnats belonging to the dipteron family Simuliidae are a terrible scourge to both man and beast in many parts of the world and have long been under suspicion as vectors of disease. In 1926 Blacklock [59] reported *Simulium damnosum* Theob. as the vector of the filarial worm *Onchocerca volvulus* (Leuckart) the causal agent of onchocerciasis. In 1934 O'Roke [60] reported *Simulium venustum* Say as the vector of a disease of ducks caused by *Leucocytozoön anatis* Wickware.

Tularaemia also known as Pahvant Valley Plague (Utah, U. S. A.) or deer fly fever was shown by Francis and Mayne [61] in 1921 to be carried from rodent to rodent by the tabanid fly, *Chrysops discalis* Williston, and presumably from rodent to man in the same manner. The causative organism of this disease, *Pasteurella* (=*Bacterium*) *tularensis*, was described in 1911 by McCoy and Chapin as the cause of a plague-like

disease of California ground squirrels. Though transmitted in nature by the deer fly and several other species of arthropods, particularly the tick, *Dermacentor andersoni* Stiles, which is involved hereditarily, the infection is most commonly contracted by handling infected rabbits.

In 1933 Kelser[62] announced that he had succeeded in transmitting the virus of equine encephalomyelitis from inoculated guinea pigs to a horse by the bite of the mosquito, *Aedes aegypti* (Linn.).

Both historically and for future investigation the relation which the protozoön subfamily Herpetomoninae of Castellani and Chalmers bears to insects and their relation to animal and plant diseases, is one of great interest to parasitologists. Numerous insects are known to harbor Leptomonas (inclusive of Herpetomonas), Crithidia, Leishmania and other genera, some of doubtful classification, but the problem of segregating those which are zoö- and phytopathogenic from those which are merely entomoparasitic is exceedingly difficult and fraught with snares and pitfalls. Apparently the earliest discovery in this connection concerning plants was made by Lafont[63] in 1910 when he demonstrated that *Leptomonas davidi* Lafont, the cause of "flagellosis" in three species of Euphorbiaceae, required as its intermediary host the bug, *Nysius euphorbias* Horvath.

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CHAPTER II

SCOPE AND METHOD

Scope and aim.—The brief historical outline of the growth of knowledge concerning the relation of insects to disease as presented in the preceding chapter will in itself give the student some understanding of the scope of medical entomology.

When in about 1909 the term medical entomology [1] first came into use to designate this field, there were many who ridiculed our enthusiasm, minimizing the importance of arthropods as vectors of disease. Today this subject takes equal rank with some of the older sciences fundamental to the field of public health and preventive medicine.

Medical entomology may be defined as the science which deals with the relation of insects and other arthropods to diseases of man and beast both as casual agents and as vectors; it is concerned with the biology and control of the arthropods involved. It contributes to the conservation of the public health and the health and well being of animals. The medical entomologist must be well trained in zoölogy and entomology as well as in protozoölogy, helminthology, and bacteriology. Training in zoölogy must include courses in both vertebrate and invertebrate zoölogy with particular stress on ecology. The former because many insect-borne diseases are maintained in nature in vertebrate reservoir animals; and the latter because a wider knowledge of invertebrates (particularly fresh-water forms) is required than is included in the usual entomological courses, and also because a better knowledge of zoölogical relationships is thus acquired. Although mycology is not looked upon as essential, the author has derived enough benefit from such a course to feel inclined to recommend the subject to his students. Much direct benefit will be derived from many of the courses given in the medical and public health curricula such as general anatomy, general physiology, epidemiology, histology, pathology, haematology, and coprology. In order to appreciate certain problems in field operations against mosquitoes and flies, for example, one ought to have some knowledge of the field of sanitary engineering as it pertains to drainage and sewage disposal. Knowledge of the subjects above suggested cannot replace the professional services of physicians, sanitary engineers, epidemiologists, and expert technicians, but one's appreciation of the problem as a whole is greatly enhanced by this knowledge.

Training of the sort above outlined will enable a medical entomologist to conduct a successful malaria-control campaign such as was conducted at Anderson, California.[2] In this campaign which was in charge of a medical entomologist there were engaged a physician, a diagnostician, a microscopist, a trained nurse and a gang of workmen in drainage operations.

The aim of medical entomology is the control and prevention of insect-borne diseases through the control of the vectors. Many notable examples of the service rendered by workers in this fertile field will readily occur to the student, such as the malaria and yellow fever mosquito campaigns of Cuba and the Panama Canal Zone,[3] and the heroic campaign[4] against rats and fleas in San Francisco in 1907, which resulted in the eradication of plague from that city, which if carried still further might have spread to other parts of the country. The benefit derived from this study by animal industry is well illustrated in the good effects resulting from tick control in campaigns against Texas cattle fever in the southern states.

Experimental method.—The medical entomologist must employ the experimental method if his science is to advance.[5] The experimental method is described by Thomas Hunt Morgan (1907)[6] in "Experimental Zoölogy" (by permission of the Macmillan Company, publishers) as "the most important tool of research that scientists employ. . . . The essence of the experimental method consists in requiring that every suggestion (or hypothesis) be put to the test of experiment before it is admitted to a scientific status. . . . It is the method of attacking problems that is the chief characteristic of experimental work. . . . We demand in the case of a problem in experimental science that the conditions under which an event takes place be discovered, and that, if possible, we reproduce artificially the result by controlling the conditions. In fact the control of natural phenomena is the goal of experimental work."

With the control of certain living things (insects) as one of the aims of medical entomology, it is highly important that the experimental method be used to the best advantage—medical entomologists ought to be experimentalists. The literature pertaining to this subject indicates that we are still largely in the descriptive and narrative stage of our science; however, this type of work deserves encouragement, since familiarity with the facts concerning taxonomy, anatomy, histology, physiology, development and behavior is essential to a wise use of the experimental method. Morgan (loc. cit.) again illuminates this point for us, viz.: "The carrying out of an experiment implies the formulation of a working hypothesis, and this usually presupposes some knowledge of the possible conditions that control the phenomena. The experimental work

becomes more explicit and accurate the more we know beforehand of the possible conditions that may enter into the result . . . for the highest order of work there is demanded also great imaginative power. Good judgment and accurate observation may lead to *fine* work, but constructive imagination seems to be required for the highest order of original work."

In the experimental study of insect vectors of diseases one would ordinarily first determine by experiment whether or not laboratory animals are susceptible. If laboratory animals are readily infected, then further experimentation is greatly simplified. After long years of slow advancement, knowledge concerning yellow fever made rapid strides when it became known that laboratory animals such as monkeys and white mice could be used in experimentation.[7,8] Although human malaria is evidently not transmissible to laboratory animals, an early knowledge of its vector was possible because a closely related disease occurs in birds, a study of which by MacCallum (loc. cit.) gave the key to the famous discoveries of Ross, Grassi, Bignami, and others.

Some years ago insects were suspected of being carriers of poliomyelitis. Monkeys are readily susceptible to this disease. By process of experimentation one suspected insect species after another was eliminated, such as lice, fleas, bedbugs, etc., but stable flies, *Stomoxys calcitrans* (Linn.), somehow remained under suspicion for a long time; in fact certain investigators actually announced that the disease had been successfully transmitted by these flies. Then began a long and tedious series of experiments, and after nearly a year of painstaking work negative results were published by Sawyer and Herms.[9]

Well does the author remember the test completed December 16, 1909, which proved *Diamanus montanus* (Baker) (*Ceratophyllus acutus* Baker), the ground-squirrel flea, to be a transmitter of plague from ground squirrel to ground squirrel The cage used by the U. S. Public Health Service in San Francisco for the experimental animals was an ordinary galvanized iron garbage can 33 inches high by 19 inches in diameter, suitably screened and smeared with "tanglefoot" to prevent the escape of the fleas, every possible precaution being taken to obviate danger. McCoy (1911)[10] describes the experiment:—

"A ground squirrel was inoculated subcutaneously with a broth culture of
al died on the
hyllus acutus)
were put in the cage with it. While yet warm the dead rodent was removed from the cage, and twenty-seven live fleas were taken from its body. Two of these were crushed, and staining of the resulting smears showed an abundance of pest-like bacilli in each. The twenty-five fleas remaining were put in a clean cage with a healthy squirrel. This animal died of subacute plague ten days later. . . . *This experiment is conclusive in showing that C. acutus may*

convey plague from a sick to a healthy squirrel. It should be stated that all of the squirrels were kept in quarantine for at feast a month prior to their being used for the experiment. In fact, all of these squirrels were obtained in a region in which no plague squirrels have ever been found."

Faust[11] has aptly stated, "In most experimental work with human parasitic infections laboratory animals can be utilized for all practical experimental tests, thus obviating the need for any potential risk by human volunteers. . . . Yet in certain crucial types of experimentation it has been found highly desirable to know if human host-parasite relationships are directly parallel to those of susceptible animals.

Experiments in the field of medical entomology require an unusual amount of care to prevent the escape of infected insects, also much skill and ingenuity are required in many instances in rearing these insects in the laboratory and in encouraging normal feeding responses on the part of imprisoned bloodsucking insects.

Importance of ecology.—The importance of ecological knowledge in the investigation of insect-borne diseases has been long stressed by the author. As early as 1909 (loc. cit.) it was pointed out that "It is essential that the student become familiar with the habits and habitat of the insect in the field, its life history under normal and unusual conditions." Ecology is variously defined, but few of the later proposed definitions define it so well as did Haeckel (1869) as the "relation of the animal to its organic as well as its inorganic environment." As Chapman (Animal Ecology, 1931, McGraw-Hill Book Company, Inc.) has so well said, "he considered oekologie to include the general economy of the household of nature." In at least some instances man, a member of that household, will need to learn how to live with some of these now threatening members of that same household. Man must give careful consideration to the study of the ways of these other members of that household in order that he may be able to live comfortably with them—else be may perish. Pearse[12] in a paper on the ecology of parasites points out that "Man has succeeded by changing the environment or *by changing his own characteristics* as a habitat, in ridding bimself of many of his parasites." In dealing with the importance of ecology in relation to disease Dr. Richard P. Strong[13] has well stated

"In addition to these effects of the immediate environment upon the human host, ecological studies must often consider its effects upon the intermediate hosts in instances where they exist. Here, also, climate plays an important rôle, not only in the character of the vertebrate fauna which the region harbors, but especially of the invertebrate fauna. Also, at temperatures below a certain degree, the parasites in the insects which transmit them may be unable to multiply or the insects satisfactorily to breed or even exist, as. for example, the parasites and insects concerned in the transmission of sleeping sickness and of malaria." Strong writes further, "The epidemic of malaria with its high mortality

which has recently been raging in Ceylon, India, is a striking example of the effect that climatic conditions and environment may exert upon a disease. This epidemic has occurred in what has been hitherto regarded as the most healthy and prosperous portion of the island, the southwestern part, in which there has usually been a high annual rainfall and where there has been evidence that the percentage of the population infected with malarial parasites has been but small, and hence the population relatively non-immune to the disease. This year the prevailing rains which are brought so regularly by the southwest monsoon failed to supply the usual amount of water, resulting in a prolonged drought. Then came a few heavy rains and drought again. Thus conditions arose greatly favoring the breeding of the mosquito, *Anopheles culicifacies*, which transmits the disease in this region, as many shallow pools were formed along the river beds and streams. Through these innumerable temporary breeding places, more perfect conditions for the production of mosquitoes could probably not have been devised. The outbreak of malaria was followed by failure of the crops, also due particularly to the lack of rain. Thus the people became further impoverished and the general state of their health reduced, and within five months there were 113,811 deaths, of which 66,704 were estimated to be due to malaria."

The above illustrates the complexity of ecological problems when three animal species are involved as in malaria, namely *man*, the host; a *mosquito*, the vector; and a *plasmodium*, the parasite—each species occupying a characteristic ecological niche. The ecological problem becomes more complex when a reservoir animal is injected into the picture as in the case of relapsing fever, where again *man* is involved as the host, a *tick* as the vector, a *spirochaete* as the parasite, and a fourth species, a *chipmunk*, as the reservoir, as in Californian relapsing fever.

The student of medical entomology will do well to study carefully Uvarov,[14] "Insects and Climate," Martini's [15] "Wege der Seuchen," and Buxton's [16] "The effect of climatic conditions upon populations of insects." The latter (Buxton, p. 326) remarks, "the geographical spread of human diseases and the seasonal occurrence of certain epidemics appear to be directly due to alteration in the numbers of insects which are the essential vectors of these diseases. Our ultimate objective is to know the numbers of particular sorts of insects which are capable of infecting us with the organisms which they carry."

Control of insect-borne diseases.—The control of insect-borne diseases involves not only the control of the responsible insect vectors, often very difficult or perhaps even impossible, but also the control of the focus or source from which the insect receives its infection. Thus in the simplest form of insect transmission of disease by mechanical contamination of food and drink, the source of infection may be found in the unsanitary disposal of human excreta and other dangerous animal wastes, in which case the possibility of spread by insects may be largely overcome by correcting the defect in sanitation. The use of properly constructed fly-tight privies and septic tanks in the country would largely prevent the spread

of typhoid fever and related diseases by flies. Rodent control is intended to destroy the natural reservoirs of plague, the flea being usually only an agent, though important in the dissemination of the causative organism, *Pasteurella* (=*Bacillus*) *pestis* (Lebmann u. Neumann), from rodent to rodent and rodent to man.

Furthermore, the bandling of infectious cases is a matter of great importance, as for example the screening of yellow-fever cases during a certain stage in the course of the disease, against tbe mosquito carrier. Properly screening malaria cases against mosquitoes is also a factor in malaria control. Searching out and treating certain ambulatory cases (carriers), notably sterilization of malaria cases by medication, while offering many obstacles should not be overlooked in a program of malaria control even though insects are the sole vectors. Experience in this field, however, has proved that insect control is the safest and surest method. Rigid quarantine of typhus fever cases with the object of preventing spread by lice is imperative.

Insect control.—In the control of disease-transmitting insects, ths most vulnerable point in the life history is sought, and the most effective combative methods are then employed. This involves an intimate knowledge of life history and habits. The more familiar we ars with regard to these two factors, ths better equipped are we to cope with the problems of control.

Ths application of control measures may be either of a temporary or permanent nature. Temporary control involves holding a nuisance in check for a short time, a few hours or a few days, and requiring constant repetition, for example, the use of formaldehyde to kill flies; or pennyroyal or citronella to repel mosquitoes, or even oil as applied to mosquito-breeding pools. Permanent control, on the other hand, involves correction of breeding places by mecbanical or other means, to prevent the deposition of insect eggs, for example, the draining or filling up of unnecessary ponds and pools of standing water, in which mosquitoes may breed; the correction of irrigation defects; and the disposal of manures and organic refuse in receptacles made fly-tight or hy other means in order to forestall the hreeding of houseflies.

Permanent control measures, when feasihle, will usually be less expensive in the end, and also very much more effective than the use of temporary means in the form of insecticides, which must he applied repeatedly, with continuous expenditure of time, lahor and money. Standing water can often he drained or otherwise handled witb little expense, whereas the repeated application of oil must eventually involve greater outlay and inconvenience. To illustrate, the writer at one time observed a small pond which waa undoubtedly furnishing most of the [illegible] for the neighborhood; it was the only pond near, and was

within ten feet of a running stream lower in elevation than the pond by at least eighteen inches. This pond could have been drained very easily and would have resulted in permanent correction, yet oil was being applied regularly. The pool was evidently of no use to any one, and was within the limits of a mosquito abatement district. The common housefly, a source of so much annoyance, is commonly combated with poisons, sticky fly paper and screens, when the mere control of perhaps a single pile of horse manure would speedily give ready and permanent relief.

Results obtained in the laboratory must always be carefully checked in the field before practical use of them is made in large scale field operations. Advancement in the abatement and control of insects depends very much upon public understanding, therefore education plays an important rôle in this field. Much of the trouble can be attributed to man's stupidity, carelessness and ignorance. The medical entomologist must make use of every opportunity to dispel ignorance concerning disease-bearing arthropods. Oftentimes the ignorance of the well-educated is appalling.

Vital losses due to insects.—Comparisons between agricultural and vital losses occasioned by insects, while suggestive, are by their very nature inaccurate and confusing. However, it has been estimated that the total direct annual agricultural loss occasioned by insects in the United States is about \$2,000,000,000, inclusive of losses to forests and stored products, and Hunter [17] in 1913 (probably not greatly different now) estimated the annual vital losses (human and animal) attributed to insects at about \$358,000,000. Fernald [18] in 1926, however, estimated these vital losses at \$781,450,000, i.e., human \$350,000,000 and animal (inclusive of their products) \$431,450,000.

Hunter (loc. cit.), commenting on agricultural losses as compared with vital losses, states, "The two branches are radically different in one important respect. One deals with material losses and the other with a reduction in the vital force of a nation. Is it right to compare the loss of a human life with the loss of 28 bales of cotton or 1,700 bushels of corn? The loss in cotton or wheat might be made good in another region or during another season, but for the life that is lost there is no compensation."

Of the above total annual vital loss it is estimated that \$100,000,000 is traceable to malaria, concerning which Carter [19] has well said, "It is not in its death rate that the gravest injury of malaria lies; it is its sickness rate, in the loss of efficiency it causes rather than in the loss of life. One death from pneumonia ordinarily corresponds to about 125 sick days—work days lost; one death from typhoid fever to 450 to 500 sick days; one from tuberculosis to somewhat more than this among whites. A death from malaria, however, corresponds to from 2,000 to 4,000 sick

days. This loss of efficiency may really be doubled or trebled, for the man infected with malaria is frequently half sick all the time. The loss of efficiency caused by malaria in the country of the malarious section is beyond comparison greater than that caused by any other disease, or even by any two or three diseases combined, including typhoid fever and tuberculosis."

How much to spend on control.—The farmer can estimate fairly closely what he can afford to spend on the control of insects affecting his crops, and it occurred to the author[20] that the vital losses based on "work days lost" might offer a basis on which to proceed in estimating reasonable outlays for insect control in the present connection, of which the following is an example.

"In 1918 there were 5,887 deaths from tuberculosis in California, amounting to a loss of (5,887 × 500) 2,943,500 work days; there were 187 deaths from typhoid, amounting to a loss of (187 × 450) 84,150 work days; and 56 deaths from malaria, with a loss of (56 × 3,000) 168,000 work days; a total loss to California of about 3,200,000 work days. In control work against typhoid fever the State spent between $35,000 and $50,000 in 1918. Assuming that this amount was justified, for such it actually was, because there was a reduction of about 12 per cent in the typhoid rate for 1919, there should have been expended in malaria control between $70,000 and $100,000 because the total number of work days lost is double that of typhoid fever. As a matter of fact, the State spent about $5,000 in malaria control in 1918 and the malaria death rate went up from 1.5 per 100,000 in 1917 to 1.8 in 1918, an increase of about 20 per cent. In the matter of tuberculosis control on the typhoid basis the State should have spent about $1,750,000 in 1918, which was closely approximated, the actual amount being $1,673,000."

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CHAPTER III

PARASITES AND PARASITISM

Symbiosis and parasitism.—Biologists are not agreed as to the definition of *symbiosis*, but for our purpose it may be regarded as a condition of conjoint life existing between different organisms, and in its most perfect form the associated organisms or symbionts "are completely adapted to a life in common," while on the other hand a poor adaptation to a symbiotic existence may lead to serious pathological reactions and even "to the death of the organism that is invaded."

This interpretation of the term aymbiosis is rather far removed from the usual definition, which denotes a condition of conjoint life that is more or less beneficial to the associated organisms.

It has been well said that "it is difficult to imagine that symbiosis originated otherwise than through a preliminary stage of parasitism on the part of one or the other of the associated organisms, the conflict between them in the course of time ending in mutual adaptation." (Nuttall.[1]) When the symbiotic relationship is of benefit to both organisms (reciprocal) it may be termed *mutualism*, e.g., the tiny staphylinid beetles, *Xenoduso cova* (Lec.) and *Xenoduso montana* (Csy.), secrete a fluid which ants, *Formico rufo* Linn. and otber species, suck from glandular hairs and in return for this favor the ants feed the beetles which are said to be unable to feed themselves, hence perisb, if unassisted by the ants. Also the corn root apbid, *Aphis maidirodicis* Forbes, is cared for in a most solicitous fashion, from egg to adult, by several species of ants, *Lasius*, which feed on the so-called honeydew secreted by the aphids.

When only one of the two organisms is benefited by the symbiosis, the relationship is known as *commensalism*, e.g., a minute species of cockroach, *Attaphila fungicola* Wheeler, is said by Wheeler[2] (p. 397) (Reprinted by permission of Columbia University Press) to lick the surfaces, feeding on oily secretions of *Atta* ants, which tolerate the little roaches, "without the slightest signs of hostility." No harm, of course, results to the ants and evidently no benefit is derived by them.

Parasitism.—According to the above discussion, the definition of parasitism is well within the real meaning of the term symbiosis; however, the parasitologist instead of using the term symbionts as applied to the associated species employs the term *host*, the physically larger of these, on the one hand, and *parasite* on the other, assuming that the latter

injures the former. This conceptinn nf the relationship of the associated species has led to a commonly used definition of parasitism; namely, that it involves the process of one nrganism, the parasite, gaining nourishment or other advantage at the expense of another living organism, the host, which latter must not be destroyed as the result of this association before nt least the period of growth of the former is completed, otherwise the result would be disastrous to both the parasite and the host. It follows then that in a brnad sense "*a parasite is an organism which lives at the expense of its host, giving nothing nf value in return.*" (Stunkard 1929.[3]) The true parasites are closely tuned to the life history and habits nf the host. In spite nf the fact that the life nf a parasite is commonly regarded as an easy one, it is rigorously circumscribed and full nf dangers. It is sometimes referred to as a form nf "*hopeless specialization*," since it leads eventually to extinction, unless conceivably the parasite were nble tn work gradually back from parasitism to a free-living condition. On the other hand if parasitism is but the beginning of an ill-adapted symbiotic life, then conceivably it might gradually end through progression into a condition of mutual adaptation. Indeed Nuttall (loc. cit.) has gone so far as to point out that "it is difficult to imagine that symbiosis" (in the restricted sense, that is, mutual adaptation) "originated otherwise than through a preliminary stage of parasitism on the part of one or other of the associated nrganisms."

There are many species of insects which are parasitic on other insects and some nf these are very useful in holding certain pests in check. Such "*parasitoid*" insects, as they may best be termed, are often reared in insectaries in enormous numbers to be liberated when best suited for control purposes. This practice is known as "biological control." While not of direct concern to the medical entomologist, it is nevertheless a subject which will interest him in insect-control operations. The parasitism of

as ladybird beetles of the family Coccinellidae, also the Chrysopidae, commonly known as aphid lions. These *predators* capture their *prey* and literally eat it, while other predators, such as the kissing bugs of the family Reduviidae, suck the vital juices, but in either case the prey is killed nutright.

An interesting form of *social parasitism* nccurs in social insects such as ants and hornets, where one species lives in the colony of another species which is "deluded" into feeding bnth the adults and progeny of the invaders. It has been suggested that this form of parasitism exists among human societies as well. The extreme case as suggested by Root[4] would appear to exist among certain wasps which construct no cells of their own and do not hunt, but provide for the future of their progeny by placing

ment *corporis* imbibes larger meals at longer intervals in conformance with the resting habits of the host, while *capitis* with continuous opportunity for feeding takes a small amount of food at short intervals. Furthermore, Nuttall (loc. cit.) remarks that, "The effect of darkness no doubt is responsible for *corporis* possessing longer and slimmer antennae and legs than *capitis*. The latter is more exposed to light upon the head than is *corporis* beneath the clothing in most instances. It is, of course, well known that arthropods inhabiting dark places have longer antennae and legs than those living exposed to light." Adaptation to the skin color of the host appears to be obvious. Lice collected from the heads of the brown-skinned Gilbertese during the author's investigations among these people on Fanning Island [7] were strikingly sooty in color. Rearing lice in pill boxes of different colors inside as carried on by Nuttall[8] shows that change of color is rather easily accomplished.

Nuttall's conclusions based on the observations cited above are very interesting, namely, "There is little doubt in my mind that *capitis* is being converted into *corporis* today in nature, and that the latter, when man has become hairless, will constitute a species whose birth we are witnessing."

The wider adaptability of parasites, i.e., adaptation to different host species as compared to different parts of the body of the same host as in *Pediculus humanus* Linn. is shown in the different races of *Sarcoptes scabiei* (Linn.), the itch or mange mite of humans, swine, horses and other animals. While there appear to be specific differences in pigmentation, cuticular markings and chaetotaxy, these are not constant, though some insist on the validity of these characters. Transfer from host to host of different species can be more or less readily accomplished. Other examples could be cited to illustrate this adaptability such as certain polymorphic mammalian trypanosomes, *T. brucei* Plimmer and Bradford, *T. gambiense* and *T. rhodesiense*, as cited by Duke,[9] who refers to these as physiological variants of a single species.

The interrelation, both as to behavior and structure, between the parasite and the host becomes more perfect as the symbiosis grows more intimate. The true parasite and its host represent a type of machine with all its parts functioning coördinately, hence it is difficult to discuss the behavior of the former without also dwelling on the behavior of the latter. The stage in this relationship when the former cannot exist without the latter is certainly reached in many instances, but one may well wonder whether the reverse condition is ever actually achieved through the agency of parasitism. There are many people who believe that bots are a sign of health in a horse and humorously that a dog must have fleas to keep his mind off the fact that he is a dog.

In the case of insects which suck the blood of human beings, one is

impressed with the large degree of tolerance that is manifested toward those species which are wholly or largely dependent on man; no doubt immunity is an important factor, and in turn one wonders just how far the parasite has gone in making its blood-lust less offensive. Thus several extreme cases will illustrate what is meant. Gilbert Islanders with whom the author spent some time during the summer of 1924 will reluctantly give one a few head lice on request, but prefer keeping them for festive reasons. The body louse of an old timer is not so offensive to him as it is to a tenderfoot, and many are the weird trench stories told by soldiers concerning narrow escapes from death because of a louse and the tender return of the cootie to its warm nest. In contrast, contemplate for a moment the very serious side of the problem—lice as vectors of deadly typhus fever and other diseases.

The bite of *Anopheles maculipennis* Meigen is generally benign, the bite of *Aedes dorsalis* (Meigen), a common salt marsh species, is almost always viciously irritating. The former species has become closely associated with man and is a potent vector of the causative organism of malaria, the latter is a "wild" species. Although there will be many objectors, I believe the bite of a bedbug, *Cimex lectularius* Linn., is less irritating than the bite of a dog flea, *Ctenocephalides canis* (Curt.), and I am inclined to believe that the bite of the rat flea, *Nosopsyllus fasciatus* (Bosc), is less irritating than that of the human flea, *Pulex irritans* Linn. The bite of *Triatoma protracta* (Uhler) is very painful to most persons, and one is inclined to suggest that this species must first moderate its bite before it can become a successful disease vector. Besides adaptations of mouth parts for piercing and bloodsucking, and apparent moderation of venoms to lessen pain in the host, there is tha interesting chemical factor which prevents blood coagulation. This factor is particularly well developed in the bloodsucking helminths such as the leeches and hookworms.

The chemical phenomena due to irritants and anti-coagulants can hardly be separated from the toxic effects on the host such as urticaria following the bite of *Triatoma protracta* (Uhler) and certain paralyses traceable to *Dermacentor andersoni* Stiles.

The study of parasitism has contributed much during the past few years to the field of pathology and clinical medicine, the disturbances resulting from parasitism being usually of a specific nature, and the causes of certain symptoms heretofore unknown are now often readily accounted for on this basis.

Origin of parasitism.—Parasitism is one of the ways in which organisms acquire food and is only one of the avenues, though an important one, that bring the arthropod into relation with man and other animals as pathogenic factors. Scavenger insects with omnivorous feeding habits

such as scavenger flies and cockroaches which feed on excrement readily become food contaminators and may consequently become important factors in the dissemination of filth diseases such as typhoid fever. Also predaceous arthropods such as the black widow spider and the conenose bugs, may attack man, both introducing venoms and the latter blood parasites. While the female black widow spider probably only bites human beings in self-defense or in defense of her egg cocoon, certain reduviid bugs such as *Triatoma* actually suck the blood of sleeping persons for purposes of nourishment, though many other warm-blooded animals may also serve as hosts. It is but a short step between sucking blood by tapping the body of a bedbug which has fed on an animal and tapping the body of the animal directly. This procedure is followed in some instances at least by *Triatoma protracta* (Uhler). Various species of blood-sucking arthropods secure blood meals by tapping the abdomens of their blood-engorged associates.

Modern parasites are restricted more or less completely to particular host animals, which necessitates the deduction that the parasite must have developed its habit after the existence of the host, and in consequence parasitism must be a recently acquired habit on the part of a one-time free-living organism. This becomes more apparent by a study of the life history of the parasite; invariably the earlier stages point to a primitively free-living existence. Perhaps the ancestors of a given group of modern parasites were attracted to waste food, offal and exudations of certain animals; the search for food having become simplified, they began living as messmates, or commensalists, or as scavengers; the association between the two species became closer and eventually the line of parasitism was completed. This is also borne out by a study of the nearest allies of a given parasite, in which the gradation from the free-living animal to the parasite may be traced. The very close structural similarity between the free-living, wingless book louse, *Troctes divinatoria* (Müll.) (a member of the order Psocoptera, family Psocidae), and a common hen louse, *Menopon pallidum* Nitzsch (a member of the order Mallophaga), leads us to believe that the parasitic Mallophaga have been derived from the Psocidae. Knowing the habits of the book louse, we can easily imagine how the habit of parasitism might eventually have become established; i.e., from the eating of feathers, scales, and excretions off the animal to the eating of the same on the animal as a host.

Degrees of parasitism may also be illustrated by examples from the biting lice, Mallophaga, in which there are species having the power to run freely and live for a considerable length of time off the host, e g., *Menopon pallidum* Nitzsch, the common hen louse, while other related species have become entirely sessile, as in the extreme case of the wormlike louse, *Menopon titan* Piaget, inhabiting the gular pouch of the peli-

can. Among the fleas there are also good examples of gradation in habit and structure, e.g., the human flea, *Pulex irritans* Linn., which has developed remarkable springing power and is comparatively free to move from place to place, while the mature sticktight flea, *Echidnophaga gallinacea* (Westw.), is usually quite sessile, holding fast to one spot much like a tick.

The medical entomologist is continually beset with questions concerning the early development of the present intimate relation existing between insects and causative organisms of disease. It is interesting to know that Galli-Valerio[10] found that *Herpetomonas pyrrhocoris* Zotta et Galli-Valerio lives part of the time in flagellate form in the rotting blossoms of the meadow saffron, *Colchicum autumnale*, where it is picked up apparently by the bug in the spring and is deposited in non-flagellate form again in the blossom during the autumn by means of the insect's excreta. This is believed to be a very primitive degree of the adaption of a saprophytic protozoön to an internal parasitic life in an insect. The

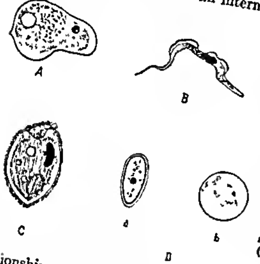

Fig 1.—Examples of Protozoa. A. Sarcodina, represented by *Endamoeba histolytica* of amoebic dysentery, B. Mastigophora, represented by *Trypanosoma gambiense* of African sleeping sickness; C Infusoria, represented by *Balantidium coli*, causative organism of a certain oriental dysentery (redrawn after Leuckart), D. Sporozoa, represented by (a) *Coccidium oviforme* from liver of rabbit, (b) *Plasmodium vivax* of malaria shown in a red blood corpuscle. (All greatly enlarged)

relationship existing between *Leptomonas davidi*, already referred to, living in the latex of *Euphorbia* and carried by the bug, *Nysius euphorbiae* Horv., represents a step in advance.

Systematic position of animal parasites.—Though parasitic animals are found in other phyla, those of economic importance affecting man and beast are included almost exclusively in the following:

a. Protozoa—unicellular animals; e g., *Endamoeba histolytica* (Schaudinn), causing amoebic dysentery; *Plasmodium vivax* (Grassi and Feletti), causing malaria; *Trypanosoma gambiense* Dutton, causing African sleeping sickness. (Fig. 1.)

b. Nemathelminthes—bilateral, unsegmented worms of cylindrical form; e g., *Trichinella spiralis* (Owen), causing trichinosis; *Ascaris lum-*

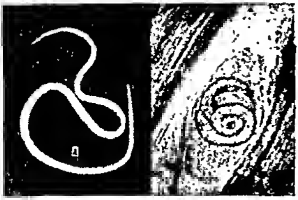

FIG 2

FIG. 3

FIG. 2.—Examples of parasitic round worms (Phylum Nemathelminthes, Class Nematoda). *a*. Round worm of swine (*Ascaris lumbricoides*); *b*. *Trichinella spiralis*, greatly enlarged.

FIG. 3.—Examples of parasitic flatworms (Phylum Platyhelminthes, Class Cestoda). A poultry tapeworm (*Choanotaenia infundibulum* × 1) on the left, and a common tapeworm of cattle (*Moniezia expansa*, greatly reduced) on the right.

bricoides Linn., roundworm of man; *Ancylostoma duodenale* (Dubini), a hookworm of man. Development is usually direct. (Fig. 2.)

c. Platyhelminthes—bilateral worms; flattened dorsoventrally; no anal opening. Usually requiring an intermediate host.

1. *Cestoda*—scolex with separable segments called proglottids; e.g., *Taenia solium* Linn., the pork tapeworm of man; *Taenia saginata* Goeze, the beef tapeworm of man; *Dipylidium caninum* (Linn.), a common tapeworm of the dog. (Fig. 3.)

FIG 4

FIG. 5

FIG. 6

FIG. 4.—Example of parasitic flatworms (Phylum Platyhelminthes, Class Trematoda). A liver fluke of sheep (*Fasciola hepatica*) × 1.

FIG. 5.—Example of segmented cylindrical worms (Phylum Annelida, Class Chaetopoda). Earthworm (*Lumbricus sp.*, × .5) non parasitic, but may serve as an intermediary host for certain poultry tapeworms.

FIG. 6.—Example of segmented cylindrical worms (Phylum Annelida, Class Hirudinea). Leech (*Hirudo medicinalis*) × .5.

2. *Trematoda*—alimentary canal branched; mouth in a sucker; e.g., *Fasciola hepatica* Linn., the sheep liver fluke. (Fig. 4.)

d. Annelida—bilaterally symmetrical, segmented or annulated worms.

1. *Chaetopoda*—locomotor chaetae; segmentation extending to internal organs; e.g., *Lumbricus terrestris* Linn., a common earthworm (non-parasitic). (Fig. 5.)

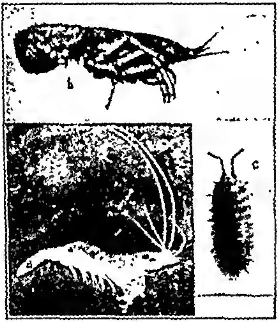

FIG. 7.—Examples of the Phylum Arthropoda, Class Crustacea. *a.* Shrimp × 1.2; *b.* Crayfish × 6; *c.* Sowbug × 2. (All three examples are non-parasitic)

2. *Hirudinea*—flattened; sucker at each end of body; arrangement of internal organs does not correspond to external segmentation; e.g., *Hirudo medicinalis* Linn., the medicinal leech. (Fig. 6.)

e. Arthropoda—segmented body with paired jointed appendages; chitinous exoskeleton; bilaterally symmetrical; heart dorsal; ventral nerve cord.

1. *Crustacea*—head and thorax often united to form a cephalothorax; numerous paired, biramous appendages; two pairs of antennae; respiration usually branchial; habitat usually aquatic; e.g., shrimp, crayfish and the sow bug (the latter terrestrial). These examples are non-parasitic. (Fig 7.)
2. *Onychophora* (*Protracheata*)—vermiform and externally unsegmented; numerous paired, imperfectly segmented legs; one

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8. Nuttall, G. H. F., 1919. The biology of *Pediculus humanus*. Parasitology, vol. xi, no. 2, pp. 201–220, pl. x.

9. Duke, H. L., 1923. Further inquiries into the zoölogical status of the polymorphic mammalian trypanosomes of Africa. Parasitology, vol. xv, pp. 358–395.

10. Galli-Valerio, B., 1920. Le cycle évolutif probable de' l'*Herpetomonas pyrrhocoris*, Zotta & Galli-Valerio. Schweiz. Med. Wochenschr., 1, 1920, pp. 401–402. (Cited in The Review of Applied Entomology, Medical and Veterinary, vol. 10, Ser. B, Part 1, p. 8, Jan., 1922.)

CHAPTER IV

HOW INSECTS AND ARACHNIDS CAUSE AND CARRY DISEASE

Insect and pathogen.—When one considers that man and his domesticated animals are so closely associated with many scores of species of insects and their kin, the wonder is that there are not more insect-borne diseases as well as direct injurious bodily effects. Many of these arthropod species have in time become definitely parasitic; burrowing into the skin as do certain mites (acariasis); invading the alimentary tract as do larvae of botflies (myiasis); and bloodsucking as are bedbugs, sucking lice, horseflies, mosquitoes, etc. Bloodsuckers by virtue of their bloodsucking habit may readily become conveyors of pathogenic blood-inhabiting microörganisms. It has been well said that no bloodsucking arthropod can be trusted; eventually many more species than are now shown to be such, will prove to be vectors of disease of man and his domesticated animals.

The medical entomologist must acquaint himself with the ecological aspects of disease-producing microörganisms. In order to know where the insect picks up the disease-producing agent and how it becomes infectious, the habits of pathogenic organisms must be studied, their habitat in the body of the diseased host must be known, the gateways of escape must be ascertained, their longevity and virulence when away from the host and many other ecological factors must be determined. After having picked up the pathogenic organism, its course within the body of the insect must be studied in order to know how it makes its escape therefrom and how it reaches the body of the next host. Thus a knowledge of the feeding habits of insects is essential.

To illustrate, bubonic plague is a bacillary disease caused by *Pasteurella pestis* of which the rat is an important host and to which man readily succumbs. While these organisms may pass from host to host in several ways, it has been found that fleas are the most important vectors. The bacilli are found in great abundance in the buboes which are situated largely in the axillary and inguinal regions of the rat, and it has been found that these regions are favored by fleas, which, due to their bloodsucking habits, imbibe the highly infectious fluids. If the rat dies of the plague, the fleas leave the cold body and seek another host; this interval in the change of hosts raises the question of the resistance and longevity of the bacilli. Can the bacilli resist the digestive fluids of the

eating. The venoms are introduced in the following ways, (1) by the bite, as in canenose bugs and black widow spiders; (2) by the sting, as in bees, wasps, scorpions; (3) by urticating hairs, as with the brown tail moth, and (4) by contact, vesicating fluids, as with blister beetles.

Dermatosis.—Various skin irritations are caused by arthropods, either by bites or skin invasions. No doubt many of these irritations could be classified just as appropriately as envenomizations, particularly because a tolerance appears to be built up when individuals are subjected to bites over a longer period of time. Skin irritations commonly result from the bites of such insects as mosquitoes, fleas, lice, and bedbugs. Various species of burrowing mites cause skin irritations commonly known as *acariasis*. Among the latter are the itch mites, *Sarcoptes scabiei* (Linn.); the scab mites, *Psoroptes communis* Hering; the follicle mites, *Demodex folliculorum* Simon; the chigger mites, *Eutrombicula alfreddugesi* (Oudemans) [*Trombicula irritans* (Riley)], and other species.

Myiasis.—An invasion by maggots, the larvae of Diptera, of organs and tissues of man and beast is termed *myiasis*. The invading maggots may be specific myiasis-producing forms, i.e., obligatory sarcobionts, invading cutaneous tissues as does *Dermatobia hominis* (Linn.) in man and *Hypoderma bovis* (DeGeer), the warble fly of cattle; invading the gastric and intestinal tract as do botflies of horses, *Gasterophilus intestinalis* (DeGeer); and invading the nasal and frontal sinuses as in the case of the head maggot of sheep, *Oestrus ovis* Linn. The invading maggots may be necrobionts or facultative sarcobionts, in which case *traumatic dermal myiasis* may result as with infestations of screwworms, *Cochliomyia americana* C. & P. Accidental myiasis may be the result of fly larvae in food, or the result of flies attracted by discharges—anal, vaginal, nasal. The larvae of blowflies, bluebottle flies and green-bottle flies commonly occur in accidental intestinal as well as traumatic myiasis.

Allergy caused by insects.—A condition of persons' being specifically sensitized to certain insect proteins is a fairly common and widespread phenomenon. Persons working habitually with bees or collections of dead insects, or exposed for longer periods to pulverized insect parts, scales of butterflies, moths and caddis flies, or residents about lakes where cast skins of mayflies abound, are frequently subject to attacks of asthma and other disturbances the result of allergens (Figley 1929).[5]

Mechanical (simple) carriers of infection.—Many species of insects may accidentally contribute to the portage of various filth diseases; however, when insects habitually and alternately feed and/or breed in excrement and then feed on human food prepared for the table, they may actually become food and milk contaminators and a menace to the pub-

lic health. Such are flies, particularly the common housefly, and cockroaches. The causal organisms of filth diseases, such as typhoid fever, cholera, and amoebiasis may adhere to the mouth parts and feet of these insects and may then be deposited on human food and infection result. The mechanical transmission of yaws (a spirochaete infection), and certain eye infections (so-called pinkeye) are similarly effected by muscid flies and Hippelates flies. The eggs of helminthic parasites, notably pinworms [*Enterobius vermicularis* (Linn.)] may also be so disseminated. Not only do pathogenic bacteria, protozoa, and helminthic ova cling to the mouth parts, feet, wings, and other parts of the insect body, but they may also be swallowed by the insect and pass uninjured through its alimentary canal and be deposited on food with the insects' feces (fly specks) or be regurgitated with similar effect.

It has been amply proved that coprophagous fly larvae (maggots) which feed on and develop in human excrement may pass on bacteria taken up in this stage through the pupal stage and as a result become infected mature flies. In this manner the infection of anthrax (*Bacillus anthracis*) may be disseminated by fleshflies, bred in carcasses of animals dead of this disease. This is a strong argument in favor of the incineration of the bodies of dead animals.

Another purely mechanical method of disease transmission is by means of *contaminated piercing* mouth parts, in which these organs in the act of feeding become contaminated with blood-inhabiting pathogenic organisms, and *simple inoculation* follows. Here again as in the aforementioned cases, the pathogenic organisms undergo no developmental change. Insects that belong to this class of simple carriers generally have strong, piercing mouth parts, capable of drawing considerable blood and are intermittent feeders, going readily and quickly from one host to another, e.g., the horseflies (Tabanidae), which are ready vectors of anthrax in this manner.

Cyclico-propagative transmission.—Of the several ways in which biological transmission by arthropods is effected, the *cyclico-propagative* type is the one most likely to be used to illustrate insect transmission of disease; however, Huff [4] has pointed out that there are actually at least two other ways in which this occurs, namely, *cyclico-developmental* and *propagative*. In the *cyclico-propagative* type of transmission the causal organisms "undergo cyclical change and multiply" in the body of the arthropod as in the transmission of malaria plasmodia by anophelines and in the transmission of *Babesia bigemina* of Texas cattle fever by the Texas fever tick.

Cyclico-developmental transmission.—When the causative organisms "undergo cyclical change but do not multiply" in the body of the arthropod, transmission may be classed as *cyclico-developmental* as in

insectivorous animals use arthropods as intermediate hosts. Since many of the vertebrate hosts are aquatic or semiaquatic, so most of the arthropods are also aquatic, such as dragonflies (Odonata), caseworms (Trichoptera), may flies (Ephemerida), and stone flies (Plecoptera). Among these flukes are the poultry fluke, *Prosthogonimus pellucidos* (v. Linstow), particularly of ducks, which use the larvae of the dragonfly, *Libellula quadrimoculata* Linn., as intermediary host. The important lung fluke of man, *Parogonimus westermoni* (Kerbert), requires as its second intermediary host (the first is a melaniid snail) a crustacean, *Astacus spp.*, crayfish.

Among the Nematoda (threadworms) are numerous species that use arthropods as intermediate hosts; among these are the *Gongylonema* worms (Spiruridae) such as *G. pulchrum* Molin, which causes an infection of humans (also pig, sheep, ox, etc.) known as gongylonemiasis. These worms occur as larvae in such insects as cockroaches (Blattidae), meal worms (Tenebrionidae) and a few other forms. The mature worms, extremely slender (0.5 mm. diameter), reach a length of 140 mm. in the female. In the vertebrate hosts the worms are found in burrows of the mucosa and submucosa of the mouth, tongue and oesophagus. The eggs are evacuated with the fecal material of the host and do not develop until taken up and swallowed by an insect. The eggs hatch in the digestive tract of the insect and soon penetrate the intestinal wall, coming to rest as encapsulated larvae in the body cavity. There they remain until the insect is ingested intact or in fragments by an appropriate vertebrate host. Here the larvae are freed and soon migrate along the digestive tract to the oral cavity where they mature. Sambon [8] based his deductions concerning cancer on a study of *Gongylonema* worms. (See Chapter VII.)

Other nematodes which require arthropods as intermediate hosts are certain species belonging to the family Filariidae such as *Wuchereria bancrofti* and *Onchocerca volvulus*, the former requiring mosquitoes and the latter black gnats (see later chapters).

The thornheaded worms (*Acanthocephala*) use beetles (Scarabaeidae) mainly as intermediate hosts, e.g., the thornheaded worm of swine, *Macracanthorhynchus hirudinoceus* (Pallas).

The famous guinea worm of the Nile Valley and equatorial Africa, *Dracunculus medinensis* (Linn.), a worm which as an adult female may measure from 70 to 120 cm. in length, requires Crustacea belonging to the genus *Cyclops* as intermediate hosts.

Reservoir animals.—Reservoir animals play an important rôle in the natural distribution of insect-borne diseases. Since true reservoir animals suffer little or no ill effect from certain microörganisms pathogenic to

man their presence may go unnoticed, as is the case with rabbit reservoirs of Rocky Mountain spotted fever; however, rat epizoötics are commonly the forerunners of human plague epidemics. The human being may himself be a reservoir of certain insect-borne infections, even plague. Since there are numerous vertebrates which serve as reservoirs, it behooves the medical entomologist to acquaint himself thoroughly with the subject of vertebrate zoölogy, already referred to, particularly the ecological aspects as well as the study of the parasitic ectozoa of wild animals, which may be more or less closely associated with man.

Referring to rats and plague again, it should be pointed out that not all species of rats are equally important, thus the brown rat, *Rattus norvegicus norvegicus* (Erxleben), because of its very habits, burrowing rather than climbing, is of less importance as the source of human plague infection than is the roof rat, *Rattus rattus alexandrinus* (Geoff.-St. Hil. and Aud.), a climbing rat, and the black rat, *Rattus rattus rattus* (Linn.). The plague problem is made more complicated because of the fact that many other wild animals serve as reservoirs, particularly the western American species of ground squirrels such as *Citellus beecheyi beecheyi* (Richardson). According to Stallybrass, "The Principles of Epidemiology" (1931), from such rodents of southeastern Russia as the susliks (*Citellus*) and jerboas (*Alactoga, Rhombomys*) "have proceeded two of the most devastating epidemics that have afflicted mankind." At least seventy species of mammals are cited as possible reservoirs of plague. This fact offers ample room for the study of their siphonapteron (flea) parasites in their taxonomic and biological relationships.

The rickettsial infections are notable for their wild animal reservoirs, namely Rocky Mountain spotted fever with its rabbits, badgers, woodchucks and others; typhus fever and rats; Japanese flood fever and voles. The spirochaete infections are equally noteworthy in that the relapsing-fever reservoirs are evidently fairly numerous; thus young porcupines have been listed as well as the armadillo and opossum, also certain ground squirrels and chipmunks in California. Trypanosome infections are well represented by sleeping sickness with its numerous big game reservoirs, and Chagas' disease with its armadillos, opossums, and dogs.

Recently a remarkable suggestion has been made by Maldonado, reported in the Bulletin de la Société Pathologie Exotique, vol. xxiv, no. 1, pp. 27–28, that certain plants may act as reservoirs of the causative organism of verruga, a disease of man, and that the species of *Phlebotomus* flies that transmit the disease may feed on the latex. It is also suggested that this would explain why these sand flies are so abundant during the rains (January to April) when this particular plant growth (*Jatropa basiacantha* and *Orthopterygium huancui*) is most luxuriant.

pathogenic organisms may be sucked up with dejecta and passed out with the feces of the fly, and deposited on human food, either in their original virulent condition or more or less attenuated.

2. A more complicated situation exists in the case of the *Anopheles* mosquito which sucks up pathogenic organisms (plasmodia) with its meal of human blood, and these parasites undergo vital sexual changes within the body of the insect, eventually finding lodgment in the salivary glands before introduction by the "bite" into the next human victim. The insect in this case is essential.

Digestive system.—There are three distinct regions to the insect intestine (Fig. 12); namely, (1) the *fore-gut*, consisting of the mouth, pharynx, oesophagus, crop and proventriculus; (2) *the mid-gut*, comprising the stomach; and (3) the *hind-gut* consisting of the ileum, colon, rectum and anus. The crop presents merely a widened portion of the oesophagus in the more generalized forms and serves as a food receptacle. In the more specialized groups, such as the Diptera and Lepidoptera, the crop is expanded into a capacious pocket or pouch. In such forms as the cockroach and grasshopper the proventriculus consists of a highly muscular dilation provided internally with chitinous teeth for grinding or straining food. The stomach is a simple sac into which open the *gastric caeca*, generally few in number, which give rise to certain digestive fluids. At both ends of the stomach are located valves which control the flow of the food. There is much variation in the length and degree of convolution of the hind intestine, but usually the three regions mentioned, namely, ileum, colon and rectum, may be located. Emptying into the ileum are the excretory or *Malpighian tubules* varying in number and length in the various groups of insects.

The salivary system consists of a pair of salivary glands which may be lobed: they are situated within the head, often extending into the thorax. Usually each gland empties into a *salivary* duct, the two ducts emptying into a common duct which opens into the mouth at the base of the labium. In many species of insects there is present a pair of *salivary reservoirs;* these may be located near the opening of the common duct and then present a compound condition, or may be situated on either side of the oesophagus at the end of a long slender duct.

Insect classification.—The medical entomologist must be equipped with a good knowledge of the basic principles of classification, so as to enable him to place the insect at hand correctly in its proper order and family at least, and in the case of insects of sanitary importance he should be able to run the specimen down to the species with the aid of a key. To determine the *order* to which an insect belongs one need usually know only the character and structure of the wings if present and the type of the mouth parts. This will enable the student to place at least

ninety per cent of the commoner insects in their proper *orders*. Unfortunately, the parasitic forms have undergone many modifications such as reduction or loss of wings and great alteration in form, but generally the mouth parts will serve as a ready means for crude identifica-

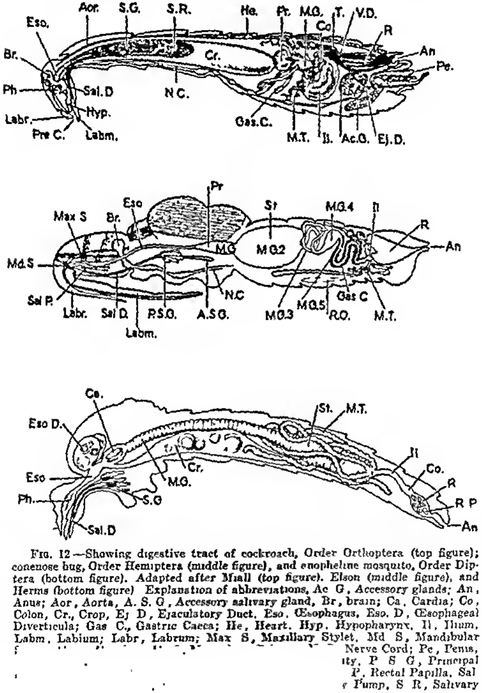


FIG. 12—Showing digestive tract of cockroach, Order Orthoptera (top figure); conenose bug, Order Hemiptera (middle figure), and anopheline mosquito, Order Diptera (bottom figure). Adapted after Miall (top figure). Elson (middle figure), and Herms (bottom figure) Explanation of abbreviations, Ac G, Accessory glands; An, Anus; Aor, Aorta, A. S. G, Accessory salivary gland, Br, brain; Ca, Cardia; Co, Colon, Cr., Crop, Ej D, Ejaculatory Duct. Eso, Œsophagus, Eso. D, Œsophageal Diverticula; Gas C., Gastric Caeca; He, Heart. Hyp. Hypopharynx. Il, Ilium, Labm. Labium; Labr, Labrum; Max S, Maxillary Stylet. Md S, Mandibular [illegible] Nerve Cord; Pe, Penis, [illegible]ity, P S G, Principal [illegible] P, Rectal Papilla, Sal [illegible] Pump, S R, Salivary

in determining the identity of the principal veins. Fig. 13b illustrates the R-C-N system * of nomenclature (Tillyard's revision) which is used in this book.

Metamorphosis.—In order to attain to the size and development of the parent, the young insect undergoes greater or less change in size, form and structure. This series of changes is termed *metamorphosis.*

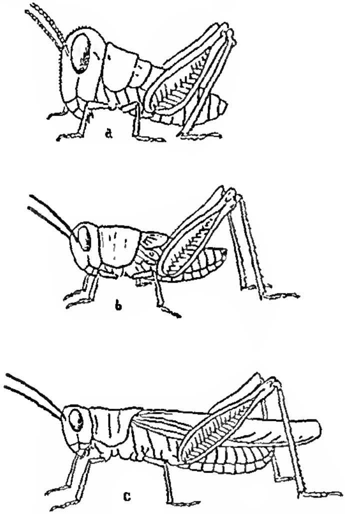


Fig. 15.—Illustrating simple metamorphosis. *a.* Young wingless grasshopper. *b.* Showing wing pads after the first molt. *c.* Adult of the same. (Redrawn after Packard.)

The least change is found in the Apterygota (silverfish and springtails), which are primitively wingless insects, and hence the newly emerged young individual is externally unlike the parent only in size: this type of metamorphosis is termed *primitive* (Fig. 14).

A greater degree of metamorphosis occurs in the grasshopper. There is not only a great difference in size, but the absence of wings in the

* Redtenbacher, Comstock and Needham.

young is at once apparent. In order to reach the winged condition, the young individual casts its skin at intervals, and with each ecdysis achieves longer wings until after a certain number of molts the fully developed wings are present. The following stages may be recognized: (1) *egg*, (2) *nymph*, (3) *imago* or sexually mature adult. This type of metamorphosis is called *simple* or *incomplete*, and the orders comprising these are known as the Heterometabola. (Fig. 15.)

The greatest difference between the newly hatched young and the parents occurs in such forms as the housefly (Fig. 16) and the butterfly. In these forms the newly hatched insect has no resemblance whatever to the adult, but looks more like a segmented worm. However, the inter-

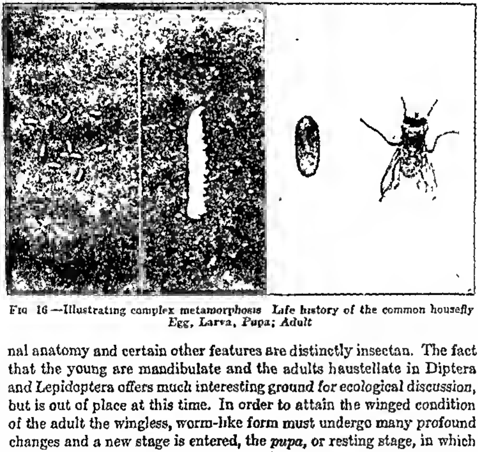


FIG 16—Illustrating complex metamorphosis Life history of the common housefly *Egg, Larva, Pupa; Adult*

nal anatomy and certain other features are distinctly insectan. The fact that the young are mandibulate and the adults haustellate in Diptera and Lepidoptera offers much interesting ground for ecological discussion, but is out of place at this time. In order to attain the winged condition of the adult the wingless, worm-like form must undergo many profound changes and a new stage is entered, the *pupa*, or resting stage, in which this transformation is accomplished. The newly hatched young insect is called the *larva*, hence the following stages: (1) *egg*, (2) *larva*, (3) *pupa*, and (4) *imago* (*adult*). This type is termed *complex* or *complete* metamorphosis, and the orders comprising these are known as the Holometabola.

External anatomy.—In order to familiarize himself with the external anatomy of insects, especially with the parts upon which classifica-

tion is mainly based, the student should study carefully some large hard-bodied insect, such as the horsefly (Fig. 17).

The orders of insects.—The following orders of the Class Insecta are commonly recognized by entomologists.

Sub-class I. Apterygota (Ap'ter-y-go'ta), apterous insects.

1. Thysanura (Thy'sa-nu'ra) (*Thysonos*, a tassel; *oura*, tail), Silverfish, Bristletails.
2. Collembola (Col-lem'bo-la) (*Colla*, glue; *embolos*, a peg), Springtails, Snow fleas.

Sub-class II. Pterygota (Pter'y-go'ta), winged insects.

Division I. Exopterygota (Exo-pter'y-go'ta).

(Heterometabola—Insects with simple metamorphosis).

3. Orthoptera (Or-thop'ter-a) (*Orthos*, straight; *pteron*, wing), Grasshoppers.
4. Dermaptera (Der-map'ter-a) (*Dermo*, skin; *pteron*, wing), Earwigs.
5. Plecoptera (Ple-cop'ter-a) (*Pleco*, plaited; *pteron*, wing), Stone flies.
6. Isoptera (I-sop'ter-a) (*Iso*, equal; *pteron*, wing), Termites.
7. Embioptera (Em-bi-op'ter-a) (*Embios*, lively; *pteron*, wing), Embiids.
8. Psocoptera (Pso-cop'ter-a) (*Psoc*, gnawing; *pteron*, wing), Psocids, Bark lice, Book lice.
9. Anoplura (An'o-plu'ra) (*Anoplos*, unarmed; *oura*, tail), True lice, Sucking lice.
10. Mallophaga (Mal-loph'a-ga) (*Mallos*, a hair; *phagein*, to eat), Bird lice, Biting lice.
11. Ephemeroptera (Eph'em-er-op'ter-a) (*Ephemeros*, living for a day; *pteron*, wing), May flies.
12. Odonata (O-don'a-ta) (*Odous*, a tooth), Dragonflies and Damsel flies.
13. Thysanoptera (Thy'sa-nop'ter-a) (*Thysanos*, a tassel; *pteron*, wing), Thrips.
14. Hemiptera (He-mip'ter-a) (*Hemi*, half; *pteron*, wing).
    a. Hemiptera-Heteroptera (*Heteros*, different; *pteron*, wing), Bugs, such as conenose bugs, squash bugs.
    b. Hemiptera-Homoptera (Ho-mop'ter-a) (*Homos*, same; *pteron*, wing), Cicadas, Treehoppers, Leafhoppers, Psyllids, Scale insects and Aphids.

Division II. Endopterygota (En-do-pter'y-go'ta).

(Holometabola—Insects with complex metamorphosis).

15. Neuroptera (Neu-rop'ter-a) (*Neuron*, nerve; *pteron*, wing), Dobson flies, Ant Lions, Lacewings.
16. Mecoptera (Me-cop'ter-a) (*Mecos*, length; *pteron*, wing), Scorpion flies.
17. Trichoptera (Tri-chop'ter-a) (*Thrix*, a hair; *pteron*, wing), Caddis flies, Case flies.
18. Lepidoptera (Lep'i-dop'ter-a) (*Lepis*, scale; *pteron*, wing), Butterflies, Moths.
19. Coleoptera (Col'e-op'ter-a) (*Coleos*, sheath; *pteron*, wing), Beetles and Weevils.
20. Strepsiptera (Strep-sip'ter-a) (*Strepsi*, twist; *pteron*, wing), Twisted-wing insects, Stylops.
21. Hymenoptera (Hy'men-op'ter-a) (*Hymen*, a membrane; *pteron*, wing), Bees, Ants, Wasps, Sawflies, Horntails, Gallflies.
22. Diptera (Dip'ter-a) (*Dis*, two; *pteron*, wing), Flies.
23. Siphonaptera (Si-pho-nap'ter-a) (*Siphon*, a tube; *apterous*, wingless), Fleas.

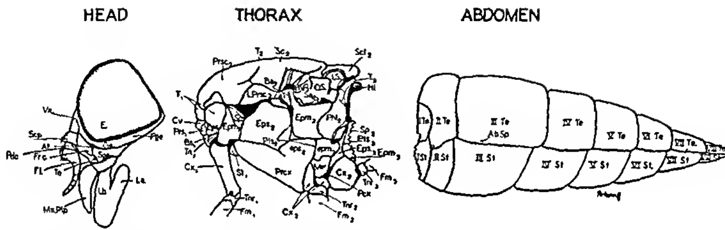


FIG. 17.—Showing external morphology of a horsefly, *Tabanus punctifer*. Explanation: Ab. Sp., abdominal spiracle; At, anterior tentorial pit; Ba., basalare; Bs, basisternum; Cv, cervical sclerite, Cx., coxa; E., eye; Epm (epm.$_2$), epimeron (Epm.$_1$ = propleuron in part; Epm$_2$ = pteropleuron; epm$_2$ = hypopleuron in part); Eps. (eps.$_2$) = episternum (Eps.$_1$, = propleuron in part; Eps.$_2$ = mesopleuron; eps.$_2$ = sternopleuron in part); Fl, flagellum of antenna; Fm, femur; Frc, frontoclypeus; Ge, gena (cheek); Hl., haltere; I. S, inner squama; La, labella; Lb, labium; L. Prsc, lobe of prescutum (notopleuron); Mer., meron (hypopleuron in part); Mx Plp., maxillary palpus; O. S, outer squama; Pcx, postcoxal bridge (postcoxale); Pdc, pedicel of antenna; Pge., postgena (occiput in part); Pls., pleural suture (sterno-, mesopleural, mesepisternal sutures); P. N., postnotum; Prcx., precoxal bridge (precoxale; sternopleuron in part); Prs, presternum; Prsc, prescutum; Sa., subalare; Sc., scutum; Scl, scutellum; Scp., scape of antenna; Sge, subgena (cheek in part); Sl, sternellum; Sp, spiracle; St sternite; To, torma; Vx., vertex; W. P., wing process.

The Arachnida.—The class Arachnida includes the ticks, mites, spiders, scorpions and related forms. Among the species of arachnids are some of the most important parasites and vectors of disease of man and beast, such as the ticks which carry spotted fever and relapsing fever of man, and others which transmit Texas cattle fever and bovine anaplasmosis. Parasitic mites cause forms of acariasis, often serious, such as mange, scabies and various forms of itch, and may, like the ticks, serve as vectors of disease, particularly Japanese flood fever.

The more important arachnids lack distinct segmentation, e.g., ticks, mites and spiders, [illegible] there are clearly segmented [illegible] the *cephalothorax* (prosoma) composed of combined head and [illegible] and second, the *abdomen* (opisthosoma). In the ticks and mites there is a strong fusion of the cephalothorax and the abdomen so that the body becomes sac-like in form.

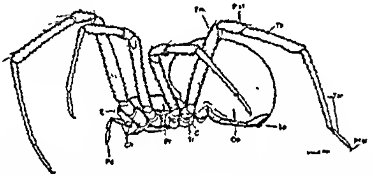


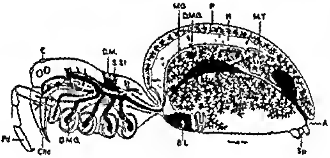
FIG. 18.—Showing external morphology of a spider. C, coxa; Ch., chelicera; E, eyes; Fm., femur; Op., opisthosoma; Pat, patella; Pd., pedipalp; Pr., prosoma; Ptar, pretarsus; Sp, spinnerets; Tar, tarsus, Tb., tibia; Tr., trochanter.

Adult arachnids with few exceptions have four pairs of legs, though the larvae of ticks and nearly all mites have but three pairs. In spiders there is a pair of pedipalpi which in scorpions, whip scorpions and pseudoscorpions are strongly chelate. All arachnids are devoid of wings and antennae. Eyes when present are simple; compound eyes are wanting. The mouth parts usually consist of a pair of piercing *chelicerae*, *pedipalpi* and in the Acarina a *hypostome*. The respiratory system of many arachnids, particularly ticks and mites, is tracheal as in insects, except that there is usually but one pair of spiracles. In spiders the respiratory organ is a combination of lung books and tracheae. There is frequently a strong sexual dimorphism in the arachnids; the males are commonly smaller than the females.

In general the arachnids are predatory and perhaps most of them are nocturnal, although there are some species of spiders and scorpions which are largely diurnal.

Arachnid development.—Arachnida deposit eggs in all the orders except the scorpions and some mites (*Pediculoides*) which are viviparous. Eggs are usually numerous, particularly in the ticks, which may deposit as many as five to six thousand. The newly hatched individuals have the general form of the adults, although the number of legs may vary, e.g., newly hatched ticks and mites usually have three pairs of legs. Development from the young to adult is gradual, no metamorphosis being involved as in the higher insects. Molting takes place as in insects, the various stages being termed instars as in the Insecta. The longevity of many arachnids is remarkable; ticks have been known to live for as many as six to seven years and some species are able to endure starvation for several years.

Internal anatomy.—The digestive tract of arachnids (Fig. 19) is characterized by various types of diverticula and branched tubules. The



diverticula which diverge from the tract between the sucking organ of the pharynx and the mesenteron, range according to Savory [2] from two short simple sacs directed forward in the cephalothorax to a condition of five pairs, four of which extend laterally and reach the bases of the legs and enter the coxae for a short distance; also a very complex type which branch and divide and become very large. From the mesenteron leads a complex system of branched tubules which occupy most of the abdomen and function partly as a digestive gland and partly as a reservoir. The Arachnida are thus enabled to store large quantities of food products and are able to undergo long periods of fasting, an adaptation which particularly favors the parasitic forms.

The excretory organs of the arachnids are Malpighian tubules which empty into the gut; and *coxal glands* which empty excretory products into tubules and discharge to the exterior from openings which vary in relation to the coxae with the several orders.

the cockroaches, grasshoppers and beetles; and (2) *haustellate*, sucking, as in the bugs, flies, bees, butterflies and moths. This classification is far from satisfactory in the field of medical entomology as is illustrated in the following cases: the common housefly, *Musca domestica* Linn., and the stable fly, *Stomoxys calcitrans* (Linn.), both possess haustellate mouth parts and belong to the same family of insects, Muscidae, hence are systematically closely related, yet are quite unrelated in their specific manner of disease transmission. By virtue of its efficient piercing stylets the stable fly has the power to pierce the skin and suck the blood, thus enabling it to become a direct infector, whereas the housefly, because of the structure of its proboscis and its inability to suck blood by piercing the skin, while probably more important as an accidental disease vector, is classed as an indirect infector or food contaminator except as before indicated.

Obviously it would be much more appropriate to classify insects as (1) piercing, e.g., mosquitoes, and (2) non-piercing, e.g., butterflies; which, however, leaves much to be desired, hence the following classification is suggested:

1. *Orthopteron type*—generalized mouth parts consisting of opposable jaws used in biting and chewing; upper and lower lips easily recognized, as in the cockroach and grasshopper.
2. *Thysanopteron type*—mouth parts representing a transitional type, minute in size; approaching the biting form, more particularly rasping, but functioning as suctorial organs; as in the thrips, the right mandible is greatly reduced or possibly even absent, causing a peculiar asymmetry shown in the drawing. (Fig. 21.)
3. *Hemipteron type*—mouth parts consisting of piercing suctorial organs, comprising four stylets closely ensheathed within the labium, forming a proboscis, as in the conenose and bedbug.
4. *Anopluran type*—mouth parts piercing-sucking concealed within the head but evertible when functioning. One pair of maxillae present; mandibles vestigial, e g., sucking lice.
5. *Dipteron type*—suctorial organs, piercing or non-piercing; no single representative is available for the entire group of Diptera, hence the following subtypes may be recognized.
   a. First subtype—mosquito; mouth parts consisting of six stylets, loosely ensheathed within the labium.
   b. Second subtype—horsefly; mouth parts consisting of six short bladelike structures used for piercing and cutting, all loosely ensheathed within the labium.
   c. Third subtype—stable fly; piercing stylets reduced to two in number, closely ensheathed within the labium.
   d. Fourth subtype—housefly; mouth parts consisting of a muscular proboscis, not suited for piercing; stylets rudimentary.
6. *Siphonapteron type*—piercing-sucking mouth parts consisting of short flaplike maxillae and stylet-like mandibles and labrum-epipharynx. The mandibles are the only cutting organs, e g., fleas.

7. *Hymenopteron type*—mouth parts consisting of suctorial, lapping organs, mandibles specialized for portage and combat, as in the bee, wasp and ant.
8. *Lepidopteron type*—mouth parts consisting of a suctorial coiled tube, as in the butterfly.

Morphology of Mouth Parts

The Orthopteron type.—To illustrate this type either the grasshopper or the cockroach may be used. This type, the mandibulate or biting, is the generalized or primitive form and will serve as a basis for later

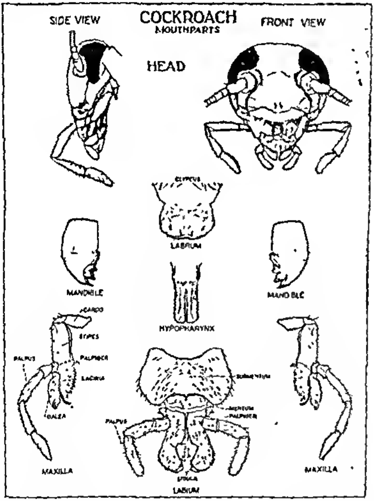


Fig. 20—Head and mouth parts of a cockroach. Orthopteron (mandibulate) type of mouth parts

comparisons and derivations. It is not directly of importance in medical entomology except as it furnishes a basis for a better understanding of the haustellate or sucking types.

If the head of a cockroach or grasshopper is viewed from the side and again from the front, the relative position of the parts will be better

understood. Separating the mouth parts (Fig. 20), the following structures will be observed. In front, low down on the head, hangs the *labrum* or lip, easily lifted as one would raise a hinged lid, the hinge line being at the lower edge of the sclerite or plate, known as the *clypeus*.

The labrum functions as does the upper lip in higher animals, i.e., it draws the food toward the mandibles. In this the labrum is greatly aided by a rough structure called the *epipharynx*, which forms the inner lining of the labrum and clypeus. Because of the close association of these two structures they are often referred to as a double organ, the *labrum-epipharynx*. Removing the labrum, a pair of heavy, black, opposable jaws, the *mandibles*, is exposed. These are biting structures *par excellence*. They are toothed and movable laterally, instead of vertically as in the vertebrates. Dislodging the mandibles brings into view the pair of maxillae, or accessory jaws. These organs are known as *first maxillae*. They are composite structures separable into *cardo*, *stipes*, *lacinia*, *galea* and *palpus*, which should be carefully observed, inasmuch as they undergo great modification in the remaining types of mouth parts. The two supporting sclerites of the maxillae are *cardo* (basal) and *stipes* (the second), while the distal lobes are (1) the *maxillary palpus* (a jointed structure), (2) the *galea* (median and fleshy), (3) the *lacinia* (inner and toothed), capable of aiding in comminuting food.

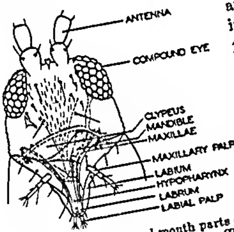


FIG. 21.—Head and mouth parts of a thrips Thysanopteron type. (Redrawn after Borden.)

Underneath the maxillae and forming the floor of the mouth lies the lower lip or *labium*, a double structure frequently called the *second maxilla*. On the same plan as the maxillae, the labium consists of a basal sclerite, the *submentum*, followed by the *mentum*, upon which rest the *labial* palpi (a pair of outer, jointed structures to the right and left), and the *ligula* (a pair of strap-like plates which together correspond to the upper lip). The labium is also subject to much modification in insects.

The fleshy organ still remaining in the mouth cavity after the parts just described have been removed is the tongue or *hypopharynx*, an organ of taste, functionally comparable to the tongue of vertebrates.

The mandibles are most useful landmarks, since they are almost universally present in insects, though in various degrees of development from the strong mandibles of certain beetles (Lucanidae) to the vestigial structures in certain Lepidoptera. In the Hymenoptera, even though the

order is of the haustellate type, the mandibles are nevertheless important structures, serving, for example, in the honeybee as wax implements and organs of defense, and in ants as organs of portage and combat. In Hemiptera and many Diptera the mandibles are modified into piercing organs while the maxillae are subjected to great modification.

Thysanopteron type.—Though like the first type, unimportant in relation to disease transmission, this type, the physopodan (Fig. 21), is

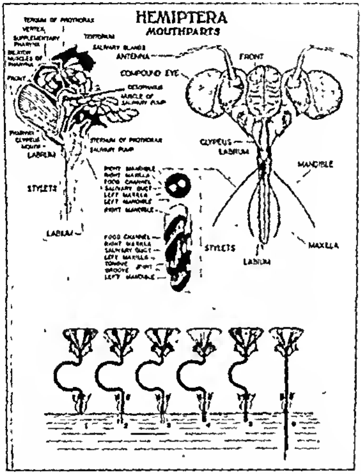


FIG. 22.—Hemipteron type of mouth parts (Adapted after various authors)

distinctly important phylogenetically as a connecting link between the biting and piercing-sucking mouth parts. It is in the very minute thrips, order Thysanoptera, that we find a transitional type of mouth parts, biting in general structure but sucking in function. According to various authors the right mandible is reduced and by others said to be entirely wanting, making the head and mouth parts asymmetrical; the left mandible, maxillae and hypopharynx are elongate, suggesting the stylet of

the piercing type, and adapted to move in and out through a circular opening at the apex of the head. No food channel is formed, but the sap is lapped up as it exudes from the abraded surface.

Hemipteron type.—A very different sort of organ from those above described is found in the order Hemiptera (Fig. 22). Here the labium forms a prominent proboscis which is usually three- or four- (rarely one- or two-) jointed and telescopic. The proboscis encloses a pair of *mandibles*, often provided with terminal barbs, and a pair of *maxillae*, all

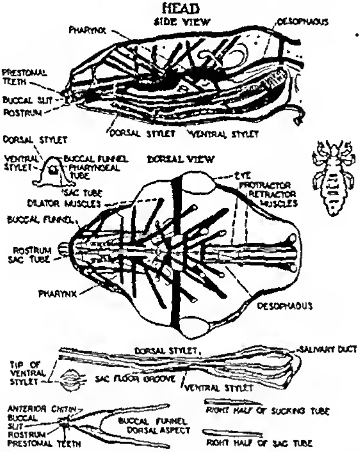


FIG. 23.—Head and mouth parts of a sucking louse. Anopluron type of mouth parts. (Redrawn and adapted after various authors.)

stylet-like and of great efficiency in piercing the skin, the maxillae operating as a unit with the mandibles functioning separately. The maxillae are closely apposed, forming the food and salivary tubes, with the mandibles aiding in rigidity. The *labrum* is quite short and inconspicuous.

Anopluron type.—The mouth parts of the Anoplura (sucking lice) are distinctly sucking in function but lie concealed within the head (Fig. 23). The mouth opening is situated at the extreme anterior portion

of the head and is encircled with a crown of minute chitinous retractile hooklets which serve as anchorage when everted. The piercing apparatus lies within a sac which opens into the mouth and consists of *maxillae* situated dorsally (the mandibles are vestigial); the *hypopharynx* and the *labium*, both stylet-like, are attached posteriorly to the walls of the enclosing sac. The apposed maxillae form the food duct and the hypopharynx forms the salivary channel. In the act of biting these parts are

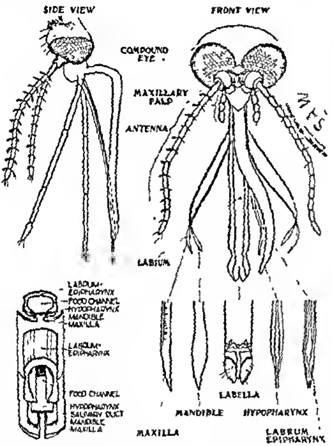


FIG. 24.—Head and mouth parts of a mosquito Side view of *Anopheles sp.* and front view of *Culex. sp.* with piercing stylets exposed (Redrawn and adapted after various authors)

pushed forward into the skin by intricate muscular action when firm attachment has been made by means of the circlet or oral evertible teeth. Salivary secretion which acts as an anticoaglin is poured into the wound and the pharyngeal pump draws blood into the pharynx and the intestine of the louse.

Dipteron type.—(a) *First subtype, the mosquito.*—The most generalized type of dipteron mouth parts is found in the mosquito (Fig. 24), hence here we find the maximum number of stylets representing the

structures of the more generalized type, loosely ensheathed within the elongated *labium*, the whole forming a prominent beak or proboscis. The identity of the six stylets is well established, and it is generally accepted that they represent the two mandibles, the two *maxillae* (distinctly serrated distally), the *hypopharynx*, and the *labrum-epipharynx*. The *palpi* are conspicuous structures in all mosquitoes. These represent the *maxillary palpi* of the grasshopper, while the pair of flattened lobe-like

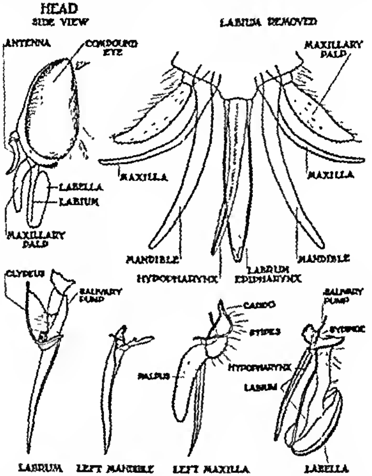


FIG. 25—Head and mouth parts of a horsefly. (In part redrawn after Snodgrass)

organs forming the distal portion of the proboscis are said to represent the *labial palpi* and are called the *labella*.

The mouth parts of male mosquitoes are subject to considerable modification; reduction in size and strength of the mandibles and maxillae is pronounced. These differences often occur in other Diptera.

(b) *Second subtype, the horsefly.*—While retaining the same number of parts as the mosquito, this subtype is distinctly characterized by its flattened blade-like condition (Fig. 25). That these mouth parts serve primarily as cutting structures is evident from the quantity of blood

usually drawn by the "bite" of a horsefly, especially one of the larger species such as the black horsefly (*Tabanus atratus* Fabr.). The *labium* is the conspicuous median portion loosely ensheathing the blades and terminating in large *labella*. The *mandibles* are distinctly flattened and saber-like, while the *maxillae* are narrower and provided with conspicuous *palpi*. The *hypopharynx* and *labrum-epipharynx* are both lancet-like. In the male these piercing parts are very weakly developed and are not useful as weapons of attack.

(c) *Third subtype, the stable fly.*—This subtype (Fig. 26) is represented by a group of flies in which the mouth parts are distinctly specialized for piercing, and show, together with the next subtype, to what

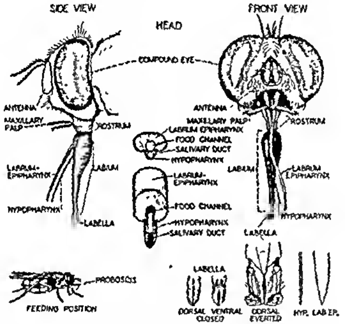


FIG. 26.—Head and mouth parts of the stablefly. (Redrawn and adapted after various authors.)

extent these structures may become differentiated within the same family of insects.

The proboscis at rest is carried at the position of a bayonet at charge, and is therefore provided with a prominent muscular elbow or knee. This conspicuous organ (the proboscis) is the *labium* terminating in the *labella*, which are provided with a complex series of cutting and adhesive structures. Within the folds of the labium and easily removable through the upper groove lie two setae, the *labrum*, the uppermost and heavier stylet, and the *hypopharynx*, a lower and weaker one, the two forming a sucking tube supported within the folds of the labium. The *maxillary palpi* are located at the proximal end of the proboscis.

(d) *Fourth subtype, the housefly.*—Here (Fig. 27) the prominent fleshy proboscis consists mainly of the *labium*, which terminates in a pair of corrugated rasping organs, the *labella*, and is attached in elbow-like form to the elongated head. The entire structure is highly muscular and may be either protruded in feeding or partially withdrawn while at rest. Lying on top of the grooved labium is the inconspicuous spade-like *labrum*, which forms, with the hypopharynx, a sucking tube, supported

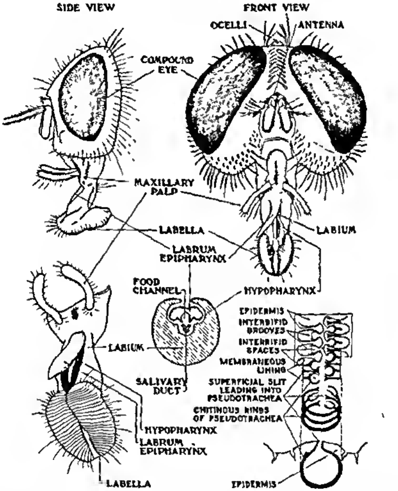


FIG. 27.—Head and mouth parts of the common housefly. Lower right hand figure shows detailed cross-section of a pseudotrachea in the labella. (Redrawn and adapted after various authors)

by the labium, which latter also encloses the salivary canal. By an examination of the labrum it will be seen that it forms a sort of convex covering to the concaved hypopharynx, thus giving rise to a food tube. The maxillae have evidently become fused with the fleshy elbow of the proboscis and only the prominent *maxillary palpi* remain.

(e) *Fifth subtype, the louse fly.*—The louse flies, members of the family Hippoboscidae, have mouth parts closely related to the third sub-

type, the stable fly; the characteristic tubular or cylindrical haustellum is adapted for penetration into the skin of the host. The *labrum-epipharynx* is stylet-shaped and its proximal portion is strongly chitinized and rigid, whereas the distal end is membranous and very flexible.[1] The hypopharynx in the two common species, *Pseudolynchia canariensis* (Macq.) [*Lynchia maura* (Bigot)] and *Melophagus ovinus* (Linn), is nearly as long as the combined haustellum and labellum, and is a very slender and hyaline mouth part.

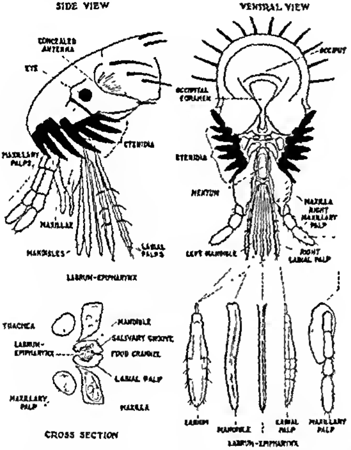


FIG. 28.—Head and mouth parts of a flea. (Redrawn and adapted after various authors)

Siphonapteron type.—The mouth parts of the Siphonaptera (fleas) (Fig. 28) represent a generalized sucking type, somewhat related to the horsefly type of the Diptera bearing long *labial* and *maxillary palpi*. The long rapier-like *mandibles* are the only cutting organs which by close apposition to the *labrum-epipharynx* form the food channel. In addition the mandibles are grooved on their inner surfaces ventrally, forming the salivary tube by apposition. The labrum-epipharynx is long and slender

but blunt distally. It is rolled scroll-like ventrally and is partially surrounded by the mandibles, thus forming the food channel. The *maxillae* are short, broad plates which do not function in biting. The short *hypopharynx* projects into the food canal at the base of the mandibles and forms the floor of the food channel. The *labium* consists of a short median body hollowed anteriorly and bearing labial palps distally. The wound

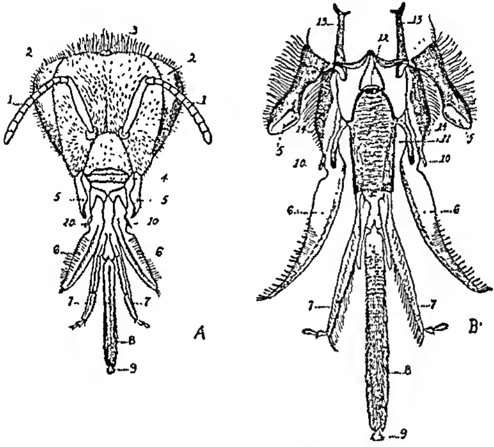


FIG. 29—Head and mouth parts of the honeybee *(Apis Mellifica)*. Both types of mouth parts well developed, but the mandibles are used chiefly for portage and modeling. (Hymenopteron type.) A. Front view of the head showing (1) antennae, (2) compound eyes, (3) simple eye, (4) labrum, (5) mandibles, (6) maxillae (galea), (7) labium (palpi only), (8) labium (glossa). B. Mouth parts removed to show the parts, (5) mandibles, (6) maxillae (lacinia), (7) labium (palpi only), (8) labium (glossa), (9) bouton, (10) maxillary palpus, (11) prementum, (12) mentum, (13) cardo, (14) stipes.

is made by the protraction and retraction of the mandibles only. As soon as the blood begins to flow, it is sucked up into the pharynx by the action of the pharyngeal pump.

Hymenopteron type.—In this type the two general classes of mouth structures, the *mandibulate* and *haustellate*, find full development in the same species, though the mandibles are not involved in the feeding

process. The honeybee (Fig. 29) serves as a representative species. The *labrum* is narrow and quite simple, the *mandibles* are easily distinguishable and are useful wox implements. In ants the mandibles are highly efficient carrying organs and weopons of defense. The *moxilloe* form the lateral conspicuous wings of the suctorial parts; the *lacinio* and *galeo* are fused and the *moxillory polpi* are minute. The *lobium* is represented by the *long structures to the right and left of the middle tube which is probably the hypophorynx.* The hypopharynx terminates in the spoon-like labellum or *bouton* which completes the lapping chorocter af the subtype.

Lepidapteron type.—This type, represented by the commoner butterflies and moths, is typically a coiled, sucking tube capable of great elongation. Taking the cabbage butterfly, *Pieris ropoe* (Linn.), as an example (Fig. 30) the *labrum* is seen to be greatly reduced, the mandibles

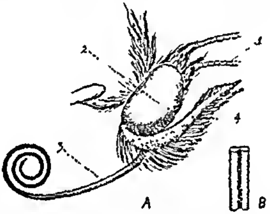


Fig. 30.—Head and mouth parts of a butterfly (*Vanessa sp.*). (A) Side view. Suctorial, coiled tube, Lepidopteron type (1) antennae, (2) compound eye, (3) proboscis, consisting only of the galeae, (4) labial palpus. (The labrum is not visible in side view.) (B) Section of proboscis showing double nature.

absent. (These may be weakly present in the lawer Lepidoptera.) The maxillae are apparently only represented by the *goleae*, which by close approximatian af their inner grooved surfaces form the long coiled proboscis. The dauble structure of the proboscis can be easily demanstrated by manipulation. The *labium* is represented by the *labial palpi.*

Orders of Insects Arronged Accarding to Mauth Parts with Type of Metomorphasis Indicated

I. *Orthopteron type.**—Biting ar chewing mauth parts.
   1. Order Thysanura—silverfish, bristletails; mouth parts entognathous or ectognathous; metamorphosis primitive.

*The term orthopteron is here merely applied to indicate a biting type which varies considerably even in the order Orthoptera.

2. Order Collembola—springtails, snow fleas; mouth parts entognathous; metamorphosis primitive.
3. Order Orthoptera—grasshoppers, cockroaches; metamorphosis simple.
4. Order Dermaptera—earwigs; simple metamorphosis.
5. Order Plecoptera—stone flies; mouth parts often reduced; metamorphosis simple.
6. Order Isoptera—termites; simple metamorphosis.
7. Order Embioptera—embiids; simple metamorphosis in male, primitive in female.
8. Order Psocoptera—psocids, bark lice, book lice; primitive or simple metamorphosis.
9. Order Mallophaga—biting lice, bird lice; simple metamorphosis.
10. Order Ephemeroptera—may flies; mouth parts vestigial; simple metamorphosis.
11. Order Odonata—dragonflies, damsel flies; simple metamorphosis.
12. Order Neuroptera—Dobson flies, ant lions, lacewings; simple metamorphosis.
13. Order Mecoptera—scorpion flies; mouth parts prolonged into a beak with mandibles at the tip; complex metamorphosis.
14. Order Trichoptera—caddis flies (moth-like); complex metamorphosis.
15. Order Coleoptera—beetles; complex metamorphosis.
16. Order Strepsiptera—twisted-wing parasites; metamorphosis complex with hypermetamorphosis.

II. *Thysanopteron type*—Rasping-sucking; biting in structure but sucking [illegible] represents a transi- [illegible]

17. [illegible] s.

III. *Hemipteron type.*—Elongated typically 3- or 4-segmented proboscis, snugly enclosing stylet-like mandibles and maxillae; piercing and suctorial.

18. Order Hemiptera (including Homoptera)—bugs, bedbugs, conenoses, cicadas, treehoppers, aphids; simple metamorphosis.

IV. *Anopluron type.*—Mouth parts piercing-sucking, completely withdrawn in head when not in use; mandibles wanting or reduced; maxillae, hypopharynx and labium form functional stylets. Circlet of oral evertible teeth provide attachment.

19. Order Anoplura—The sucking lice; simple metamorphosis.

V. *Dipteron type.*—Unsegmented proboscis, which may or may not contain piercing stylets.

20. Order Diptera—mosquitoes, flies, *et al.*; complex metamorphosis.
    a. First subtype—mosquito—loosely ensheathed, piercing, delicate, stylet-like structures, six in number, suctorial.
    b. Second subtype—horsefly—piercing, bladelike structures, six in number; suctorial.
    c. Third subtype—stable fly—closely ensheathed, piercing heavy stylet-like structures, two in number; suctorial.
    d. Fourth subtype—housefly—fleshy, non-piercing; suctorial.
    e. Fifth subtype—louse fly—cylindrical, with stylet-like piercing structures, suctorial. Closely related to stable fly.

VI. *Siphonapteron type.*—Mandibles are cutting organs, which by close apposition to the labrum-epipharynx form the food channel; maxillae do not function in biting; cutting-piercing-sucking in function.

21. Order Siphonaptera—fleas; complex metamorphosis.

VII. *Hymenopteron type.*—For feeding purposes the mouth parts are of a non-piercing, lapping type, but for purposes of combat and portage the mandibles are well developed.

22. Order Hymenoptera—ants, bees, wasps, *et al.;* complex metamorphosis.

VIII. *Lepidopteron type.*—Proboscis in the form of a greatly elongated coiled tube; non-piercing, suctorial.

23. Order Lepidoptera—moths and butterflies; complex metamorphosis.

Arachnid mouth parts.—The mouth parts of the Arachnida are essentially piercing-sucking organs, either sucking the blood (if bloodsuckers) directly from a wound made with piercing organs, or crushing the victim and then sucking the juices. In both instances sucking organs are used to draw the liquids into the stomach.

The mouth parts consist of a pair of *cheliceroe* lying in front of the oral opening and subject to great structural modification; a pair of leglike, segmented *pedipalps*, situated in the immediate vicinity of the mouth, that function variously as organs of prehension, protection, and in male spiders are specialized for use in transferring semen to the females.

In the ticks and other acari there is present a *hypostome*, functioning as a prehensile organ similar to the evertible teeth of Anoplura.

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CHAPTER VII

COCKROACHES AND BEETLES

A. The Cockroaches

Order Orthoptera, Family Blattidae

Few insects invading the household are looked upon with as much disgust as are the cockroaches. Fortunately the night prowlings of these insects and their secretive habits by day may spare the otherwise good reputation of many restaurants and hotels. The sanitary inspector, particularly the food inspector, who suggests the presence of these loathsome creatures without much strong evidence, is due to have a good argument on his hands. Evidence in material form is not always essential, for be it known to all inspectors the odor of cockroaches is difficult to conceal.

General characteristics.—Cockroaches belong to the family Blattidae of the order Orthoptera. Some authors place these insects in a separate suborder, Blattariae, which in turn is divided into several families, among them, Blattidae, Panchloridae, Panesthidae and Corydidae. Although there are numerous species (nearly a thousand being described) very few have become habitually house invaders in temperate climates and these belong to the Blattidae in a restricted sense. Roaches have characteristically dorsoventrally flattened, smooth bodies and are chestnut brown to black in color. The head is rather decidedly flexed backwards and the many segmented antennae are extremely long and slender. There are two pairs of wings when present. The wings of the males are usually well developed, while those of the females are short or vestigial in several species. The outer pair of wings (tegmina) is thick and leathery, while the inner is membranous and folds fan-like. While the fully winged forms possess the power of flight, the group as a whole is cursorial (running) in habit and can cover ground in this manner with remarkable rapidity.

The mouth parts are of the generalized orthopteron (biting) type with strong mandibles. Their food habits may be classed as almost omnivorous, with special preference for starchy and sugary materials. They attack human foods in practically all stages of preparation and apparently feed on anything that lies in their path, from the most delicate viands to the vilest excretions, even feeding upon their own cast-off skins and their dead and crippled kin. They feed at night, being typically noc-

turnal in habit. Where during the daytime everything may appear to be free from these pests when abundant, one may hear the crackling of their bodies under foot at night, if one should chance to invade their haunts after dark.

Not only do roaches disgorge portions of their meal at intervals after feeding and drop their feces on unprotected surfaces, they also discharge a secretion, both from the mouth and from scent glands, which imparts a disagreeable and nauseous odor to anything with which it comes in contact, particularly food and dishes, which is very difficult to eradicate.

Life history.—The eggs of the cockroach are assembled in the body of the female in a chitinous capsule or *oötheca* (Fig. 31) which when completed is often carried by the insect for several weeks partly protruding from the abdomen. Several tropical species (*Panchloridae*) are viviparous, i.e., giving birth to living young. The individual eggs are arranged in a double row within the capsule, and in the croton bug there are usually thirteen pairs. When the young are ready to hatch, the oötheca is deposited, usually in some dark corner or crevice, and the female apparently keeps her brood close together for a short while. The young on hatching are almost white and very soft, but soon become brownish and hard and resemble the adults except for size and the absence of wings. The metamorphosis is simple. Their development is quite slow.

Fig. 31 — Egg cases (oothecae) of cockroaches. (a) oriental roach; (b) croton bug. × 3.

The young roaches molt soon after hatching and again in about four weeks and four or five times thereafter, reaching full growth usually within a year. There appears to be but one generation a year for the larger species, though no doubt temperature and food conditions have much to do with their rate of development. The small German roach may have two or three generations in a year. In colonies of roaches there are usually all stages of development present. Roaches can apparently live a long time without food or water; Holt reports in the London *Lancet* (June 3, 1916) that one individual had survived for 76 days in a Petri dish.

Species and distribution.—As household pests cockroaches are widely distributed, chiefly through maritime trading; holds of vessels as well as the crew's sleeping quarters are oftentimes overrun with these miserable pests. The most widely distributed species are the

German roach, or croton bug, *Blatella germanica* (Linn.) (Fig. 32), and the oriental roach, *Blatta orientalis* Linn. (Fig. 33). The German cockroach or "water bug" is one of the smallest species, measuring about five-eighths of an inch to the tip of the wings, which are present in both sexes. This cosmopolitan species is evidently the most common form along the north Atlantic and north Pacific coasts, as shown by observations made in Boston, New York and San Francisco. The name croton bug has been applied to this insect because of its appearance during the construction of the Croton water system of New York City. In color the insect is a muddy brown with two longitudinal stripes on the pronotum. Although principally nocturnal, like other species, it may be seen running

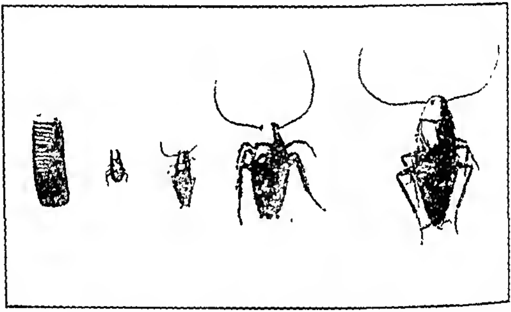

FIG 32.—The croton bug (cockroach), *Blatella (=Ectobia) germanica*, in various stages of development. The adult female is shown with egg case or ootheca in normal position protruding from the terminal abdominal segment. × 2.

about in daylight. The oriental roach is a little more than an inch in length and is very much darker than the croton bug, hence is often called "black beetle" (the term beetle being wrongly applied). The female has vestigial wings, while in the male these organs are short, reaching not quite to the tip of the abdomen. This form is common in the eastern and central states and the author has taken it in various localities in California.

Another house-infesting species is the American cockroach, *Periplaneta americana* (Linn.) (Fig. 34), a light chestnut-colored species, which reaches a length of an inch and a half to two inches and has long wings in both sexes. This is also a common species in the middle, western and southwestern states, being especially abundant in Mexico and Cen-

tral America, where it is native. It resembles a slightly shorter species occupying about the same territory in the United States, namely, *Periplaneta australasiae* (Fabr.), which differs further in that the Australian roach has a strong straw-colored line extending about one-third the way down the outer margins of the wing covers. In the Gulf Coast region the tropical cockroach, *Supella supellectilium* Serv., has become an important pest in cities. This species is somewhat smaller than the German cockroaches from which it can be distinguished by two yellow cross bands, one at the base of the wings and the other about one-sixteenth of an inch farther back. One of our commonest native outdoor species is

Fig. 33

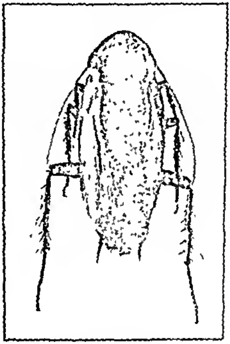

Fig. 34

Fig. 33.—The oriental roach (female), *Blatta orientalis* × 1 3
Fig 34.—The American cockroach *Periplaneta americana* × 1 3

Ischnoptera pennsylvanica (DeG). To these common forms might be added a list of exotic species constantly coming to our shores from tropical islands and from the Orient, on merchant vessels, but which have never gained a foothold. Among the commonest of these exotic species are members of the family Panchloridae such as the green Cuban roach, *Panchlora cubensis* Sauss., which frequently comes with bunches of bananas from Central America.

Roaches as carriers of infection.—Roaches as already suggested invade situations where infective excrement and sputum may occur and are actually known to feed on such matter. That they feed on human

food in practically all stages of preparation is a matter of common observation. Hence their habits readily afford ample opportunity for the contamination of food. Two questions can be easily answered by two simple experiments, namely, "Can the roach pick up specific bacteria?" To answer this question a croton bug was allowed to crawl over a culture of *Pseudomonas aeruginosa* (Schroeter) (*Bacillus pyocyaneus* Gessard), a green chromogen, in a test tube. The growth on the agar in this tube was not profuse. The insect was next transferred to a sterile agar plate upon which it was permitted to walk one minute. The roach was then liberated and transferred to a second plate for one minute, and then to a third plate in a similar manner. The agar plates were then incubated for 24 hours at a temperature of 37° C. At the end of this time a good growth of the green chromogen, *P. aeruginosa*, had developed on all three plates. Secondly, "Can the roach carry specific bacteria to human food?" Having determined in the preceding experiment that the roach can pick up known organisms, next one grain of sugar was exposed to a roach which had previously walked across an agar plate culture of *P. aeruginosa*, the same chromogen used before. The insect remained with the sugar, feeding on it for three minutes. The sugar was then dissolved in 5 cc. of sterile water and plated on three agar plates, using 1 cc. of the solution for each. The plates were incubated for 24 hours at 37° C. *P. aeruginosa* was recovered on all three plates, the growth on none being scanty. This simple experiment can easily be repeated by students who wish to prove in the laboratory that certain insects may become food contaminators.

Longfellow [1] has shown that *Escherichia coli* (Migula), *Proteus vulgaris* Hauser, *Staphylococcus aureus* Rosenbach, *S. citreus* (Migula), and a bacillus of the subtilis type are carried on the legs of roaches and that the same organisms are found in the feces, passing uninjured through the alimentary tract. However, the most important results have been obtained by Barber [2] experimenting with the roach *Periplaneta americana* (Linn.). He fed cholera dejections to roaches and found that a single insect would frequently ingest as much as 0.2 cc. In eight cases cholera vibrios were recovered from the insect's feces and in one case as long as 79 hours after feeding. After the vibrios were discharged by the roach on such moist materials as fresh beef, lettuce, etc., they remained mobile for at least 16 hours and no loss of virulence was observed when the vibrios remained in the insect's intestine as long as 29 hours. Barber also found that the roaches disgorge portions of their meal at intervals after feeding and that such disgorged material contained cholera vibrios.

The bacterial population of the croton bug.—Six individuals were selected from a collection of roaches taken from various localities and permitted to crawl for one minute over six sterile agar plates (one roach for each plate). These plates were incubated for 48 hours at 37° C.

Each plate showed a good growth, the colonies on examination proving to be saprophytic without exception.

To secure an approximate estimate of the number and kind of bacteria carried by roaches, two of these insects were treated as follows. After sterilizing pipettes, forceps, tubes, etc., 5 cc. of distilled water was placed in each of the five test tubes. Into these tubes were placed the legs and antennae of the roaches—the posterior pair of legs of one roach into one tube, those of the other roach in a second tube, the antennae of both roaches in a third, and the remaining pairs of legs of the first roach in the fourth and the remaining pairs of legs of the other roach in the fifth tube. The stomach contents were plated on agar. The tubes were shaken vigorously for three minutes in order to wash the parts well and then 1 cc. of the water in each tube was plated on agar and incubated 24 hours at 37° C. The results were all positive, as the following table (Table I) indicates:

TABLE I

SHOWING NUMBER AND KIND OF BACTERIA CARRIED ON INDIVIDUALS OF THE CROTON BUG

No. of the Roach	Part of the Roach Plated	Bacterial Count per cc.	Kind of Bacilli Present
1	Posterior pair of legs	1200*	(a) *Staphylococcus albus* (b) Non-spore-bearing bacillus
2	Posterior pair of legs	1600*	(a) *Staphylococcus albus* (b) Non-spore-bearing bacillus
1	Remaining legs	950	(a) *Staphylococcus albus* (b) Small non-spore-bearing bacillus (c) Spore-bearing air bacillus
2	Remaining legs	1200	(a) Spore-bearing air bacillus (b) *Staphylococcus albus*
1-2	Antennæ	384	(a) Spore-bearing air bacillus (b) *Staphylococcus aureus* Yellow pigment
1	Stomach contents	14	(a) Minute bacilli (unidentified)
	Total	5348*	for a dilution of ⅕

$5 \times 5348^* \div 2 = 13{,}370^*$ bacteria—minimum number present on each roach

From the above table it will be seen that each roach carried on its feet and antennae and in its stomach a minimum of 13,370 bacteria. While this does not represent a fair estimate for all roaches, since only

two individuals were used, we are here shown that the roach can carry a large number of bacteria. Esten and Mason (Storrs Agric. Exp. Sta., Bull. No. 51) have shown that the number of bacteria carried by a fly range all the way from 550 to 6,600,000, with an average of one and one-fourth million bacteria on each. Thus by comparison it may be seen that the roach probably carries fewer bacteria.

It is furthermore interesting to note that there were more bacteria on the single pair of posterior legs than on the remaining two pairs combined. This is probably explained by the use the cockroach makes of its hinder pair of legs. The tibiae and tarsi are in contact with the surface on which the insect walks, being parallel with the body. Very often the insect stands on the hind pair of legs, with the remaining legs barely touching the surface. The forelegs are also frequently brushed by the antennae.

Roaches as intermediate hosts of nematodes.—It was very early known that cockroaches may become infected with *Spirura rytipleurites* (Deslgch.) of the rat by feeding on rat feces, and that other rats may become infected in turn by feeding on roaches. Galeb, in Comptes Rendus (1878), reports that he discovered numerous parasites in the adipose tissue of the roach, *Blatta orientalis* Linn., which were found to be identical with nematodes found in the rat, *Rattus n. norvegicus*. He also found hair of the rat in the alimentary canal of the roach. On feeding rats (*Rattus r. rattus*) with infected roaches and examining them after the expiration of eight days, he found the parasites in the folds of the mucous membrane of the stomach. Several nematodes (three females and one male) had already developed sexual organs. According to Fibiger, Berliner Klinische Wochenschrift, February, 1913 (pp. 289-298), much evidence is at hand to prove that certain nematode parasites (Spiroptera) of the rat produce true malignant tumors. Eggs of these nematodes were found in the rat feces but no embryos and he reports that none developed for six months and also that rats could not be infected with the eggs, the roach being a necessary intermediate host. Two species of roaches were used, namely, *Blatta orientalis* Linn. and *Periplaneta americana* (Linn.). Ransom and Hall [8] found that although *Aphodius* beetles are the normal carriers, the croton bug, *Blatella germanica* (Linn.), might also serve as an intermediate host for *Gongylonema pulchrum* Molin, a nematode parasite of sheep and cattle. Referring to the discovery of Fibiger relative to sarcoma in rats cited above and based on his (Sambon's) epidemiological studies on human cancer Sambon (1925 loc. cit.) concluded that

"Similar to the rôle of the filaria in elephantiasis is, no doubt, that of gongylonema in cancer. Like the filaria, so the gongylonema is not the direct essential cause of the disease it gives rise to, but it probably is in certain localities, an

etiological factor of considerable importance. The gongylonema, known to be a cancer-producing agent in the rat, seems an equally likely factor in the incidence

larynx and the cardia (situations invaded by these worms) and here cockroaches, meal beetles and cellar beetles (certain beetles such as *Tenebrio* and *Blaps* of the family Tenebrionidae are suitable intermediary hosts of these worms) are an ever present vermin in the old houses in which such cancer cases occur. These observations so clearly designative of a relationship between worm and neoplasm, are strengthened by the fact that gongylonema is present and common in the majority of the domestic animals of these regions."

Although Sambon dwells particularly on Gongylonema he points out that other helminths bear a similar relationship each according to the organ which is usually invaded and in which irritation is set up, thus inviting the cancer factor. It is pointed out that cockroaches, either intact or in fragments, are only too frequently found in bread and other food which may be insufficiently cooked to kill the encysted Gongylonema, making transmission to man a simple matter.

Control.—Numerous methods have been evolved to combat the cockroaches, and it is quite certain that these insects can be controlled in dwellings, restaurants and similar places. Since roaches inhabit dark situations, one should bear in mind that daylight is the roach's greatest enemy. Open clean spaces will not harbor these pests. Old-fashioned sink cupboards invite roaches. Trapping has been found useful for the larger less abundant forms. This consists of a deep, smooth-walled vessel (fruit jar or the like) into which is placed a favorite roach food, such as chocolate or molasses (stale beer or ale are also recommended). Sticks leading to the top of the jar must be provided in order that the roaches can easily reach the mouth, and in their endeavor to get at the food, tumble into the trap If there is a liquid in the trap, the roaches are drowned, otherwise they must be killed by scalding, burning, oiling or otherwise.

Trapping methods are least successful in the control of the common cockroach or croton bug; it is certainly far more wary than the larger species. The ordinary glass-jar-trap method employed for the larger species is not effective. The croton bug can crawl up the sides of a glass jar without difficulty and thus make its escape. A dark box-trap is preferable with one or more tubular pasteboard entrances projecting both inside and outside. The mouth of the tube inside the box must be guarded either with a single trap door or adhesive substance around the outside of the tube and immediately adjacent to the mouth to prevent the roaches from escaping after feeding on the bait. The box may be baited with sugar, sweet chocolate, a little stale beer or the like. After

the roaches have been captured, they are shaken out through a lid into kerosene or hot water. The box is then once more baited and placed in position.

Dusting with sodium fluoride is by all odds the most effective means of ridding a place of roaches. Commercial sodium fluoride, either pure or diluted one-half with some inert substance such as powdered gypsum or flour, may be dusted or blown over shelves, tables, floors and the runways and hiding places of roaches. Back[4] states that "when the powder is placed where the roaches run over it, it kills chiefly as a stomach poison. It sticks to their bodies, and in cleaning themselves after running over it they transfer the powder to their mouths and thus swallow it. As a stomach poison it is slow but sure. Sodium fluoride powder is the basis of most effective roach powders sold under various trade names. It remains effective indefinitely in dry situations but in very damp places it may cake over and become useless. Applying the powder in the evening is advised, and it is best not to clean it up for 2 or 3 days. The application should be repeated at intervals of a week or two until all roaches disappear. Usually one or two thorough treatments are sufficient."

B. The Beetles

Order Coleoptera

Characteristics.—The beetles may easily be distinguished from other insects by the following characters: two pairs of wings are present of which the forward pair, the elytra, is highly chitinized or horny and does not overlap at the tip; the posterior pair is membranous and folded; the ventral portion of the abdominal segments consists of chitinous plates extending at least halfway round the body. (In other insects these ventral plates are much shorter as a rule.)

The mouth parts are of the biting type, mandibles strongly developed. The metamorphosis is complex (egg, larva, pupa, imago) with the occurrence of hypermetamorphosis in a number of species. The larvae of this order are commonly called "grubs" and may usually be recognized by the presence of three pairs of rather feeble legs.

Scavenger beetles.—All the scavenger beetles are of public health interest since the habit of feeding on dead animal matter might accidentally bring them in contact with infection. Infection may be carried in two ways, namely, first mechanically on the body, legs or mouth parts, or secondly, in the excreta. The latter method involves attenuation in that the pathogenic organism may become reduced in virulence in its passage through the alimentary canal of the insect.

Among the families of scavenger beetles are the Staphylinidae or rove beetles (not all animal feeding), recognized by the much abbreviated

condition of the wing covers (elytra), thus exposing eight abdominal segments dorsally, and giving these beetles a larval or worm-like appearance, augmented by the flexibility of these parts. The functional wings are folded up and concealed under the elytra. The range in size in this family is enormous. One very small species in the act of swarming is known to get into the eyes of people when driving, cycling or motoring, causing a severe burning sensation by means of the vile-smelling body secretions. The species commonly met with on turning over carcasses, hides, heaps of bones and other animal rubbish, belong to two genera; namely, *Creophilus* (Fig. 35 left) and *Staphylinus* (Fig. 35 right), which include species ranging from one-half to one inch in length. A second family to be considered are the Silphidae, or sexton beetles, also known as carrion beetles. In habit these insects are more decidedly scavenger than the preceding, feeding almost exclusively on dead flesh, both as larvae and adults. Again two genera will serve to illustrate the commoner forms, namely, *Silpha* (Fig. 36, left) and *Necrophorus* (Fig. 36, right). These two genera are well illustrated as to relative size and general shape by the accompanying figures.

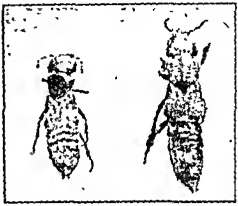

FIG 35 —Rove beetles (Staphylinidae). *a. Creophilus; b Staphylinus.* × 1 5

A third family, the Histeridae, is composed of a group of small-sized, short, shining, black beetles commonly found about decomposing animal matter.

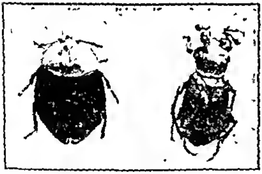

FIG 36 —Sexton beetles (Silphidae) *a Silpha americana; b. Necrophorus sp.* × 1 5.

The fourth family, Dermestidae, also includes only small forms, about one-third of an inch or less in length. In shape they are elliptical, usually dark grayish or brownish in color. Skins and other animal specimens in museums are often ruined by the museum pest, *Anthrenus museorum* Linn. or *Anthrenus verbasci* Linn (Fig. 37), if proper precautions are not taken. This damage is practically all done by the larvae, as is the case with the larder beetle, *Dermestes lardarius* Linn., and *D. vulpinus* Fabr., and the carpet beetle, *Anthrenus scrophulariae* (Linn.).

Relation to disease.—Where hides taken from anthracic animals or the carcasses are attacked by scavenger insects it is more than likely that there will be danger from this source. The following statements taken from Nuttall (loc. cit.) bear directly on this subject:

"Proust (1894), in examining goatskins taken from anthracic animals, found quantities of living *Dermestes vulpinus* Fabr. upon them. He found virulent anthrax bacilli in their excremeats, as also in the eggs and in the larvae. It is evident from this that these insects which feed on the skins permit the anthrax spores to pass uninjured through their alimentary tract. Heim (1894) also had occasion to examine some skins which were suspected of having caused anthrax in three persons engaged in handling the leather. He found larvae of *Attagenus pellio* Linn, *Anthrenus museorum* Linn. (both Dermestidae) and *Ptinus*, also fully developed insects of the latter species on the skins. All these insects had virulent anthrax bacilli (spores) on their surface and in their excreta, from which Heim concludes they might spread disease. He says the excreta are very light and easily scattered by the slightest current of air Heim does not believe the bacilli multiply in the bodies of these insects, but that the latter may be dangerous through their scattering the spores about."

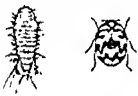

Fig 37—The varied carpet beetle, *Anthrenus verbasci*, showing larva and adult beetle.

Beetles as intermediate hosts of helminths.—Many species of beetles serve as intermediate hosts of helminthic parasites of man and animals, both wild and domesticated. This common relationship is no doubt due to the variety of feeding habits of beetles which enables them to ingest fecal matter in which eggs of intestinal parasites of animals commonly occur; thus many coprophagous beetles as well as cereal and omnivorous feeders may readily lend themselves as intermediate hosts. As suggested previously (see cockroaches) nematode worms of the genus *Gongylonema* commonly occur in the dung beetles belonging to the Scarabaeidae, such as members of the genus *Aphodius;* also in meal worms belonging to the Tenebrionidae such as *Tenebrio* sp.

May beetles or cockchafers (family Scarabaeidae) are known to be intermediate hosts both in the larval and adult stages of the thorn-headed worm, *Macroconthorhynchus hirudinoceus* (Pallas) [(*Gigantorhynchus gigas* (Bloch)], a parasite of swine also said to occur in man in rare cases. This nematode worm in its adult stage measures from 20 to 30 cm. in length and about 3 to 5 mm. in thickness, and inhabits the small intestine of its host. The eggs are deposited in this habitat and pass out with the feces which may be swallowed by the larvae of the cockchafers. These are often extremely abundant among the rootlets of grass in heavily sodded pastures, and swine with free range are exceedingly fond of these grubs, in search of which they diligently root up the soil with

their snouts. Thus every opportunity is given for the grubs to become infected and in turn the swine.

After the ova have been ingested the larvae hatch in a few days within the intestine of the insect and proceed to burrow through the intestinal wall and into the muscles, where they are said to encyst themselves. In Europe the intermediate host is commonly *Melolontha melolontha* (Linn.) and *Cetonia aurata* (Linn.).

Numerous species of beetles have been proved to be intermediate hosts of the fowl tapeworm, *Raillietina cesticillus* (Molin). The species listed by Reid, Ackert and Case [5] belong to the following families, Scarabaeidae, two species; Tenebrionidae, one species; Carabidae, subfamily Harpalinae, 26 species to which they added twelve not previously reported, giving a total of 38 species in this family. The beetles belonging to the genus *Amara* proved to be particularly favorable hosts although the largest number of cysticercoids were produced by a species of *Pterostichus*, a total of 626 by one beetle which had been fed on four proglottids.

The adult tapeworms, which measure from 10 to 12 cm. in length, are generally attached to the lumen of the upper third of the chicken intestine. The terminal gravid proglottids which break off pass from the body of the host with the feces and continue to be motile for a short time after evacuation. If the proglottids are eaten by appropriate species of beetles the hexacanth embryos develop and penetrate the intestinal wall of the host and develop into mature cysticercoids in the body cavity of the beetle in from 14 to 21 days or longer, usually 14 to 16 days during the hot part of the summer. If the beetles are now eaten by chickens the mature ovoid yellowish brown cysticercoids, which measure from 363μ to 521μ in length by 199μ to 398μ in width, according to the above investigators, are freed in the duodenum of the birds and in about two weeks adult tapeworms are produced.

The onchosphere stage of *R. cesticillus* can be distinguished from onchospheres of other species of fowl tapeworms by two funnel-like structures in the membranes which surround the hexacanth embryo, (Reid, Ackert and Case). May beetles of the genus *Lochnosterna* (according to Stiles, *Lochnosterna arcuata* Smith and others) are probably all more or less concerned. The life history of nearly all May beetles is quite long, the larval stage alone often requiring nearly three years.

In districts infested with the thorn-headed worm a systematic crusade against cockchafers would be the logical means of control, together with the treatment of swine.

Rose chafers poisonous to poultry.—The rose chafer, *Macrodactylus subspinosus* (Fab.), family Scarabaeidae, has been found to be poisonous to chickens, ducklings, goslings and young turkeys by Lam-

son.[6] He found that chickens fed in quantity on rose chafers showed the following symptoms after from four to five hours:

"Drowsy appearance, with wings drooping, the eyes closed, and a slight shaking of the body. This drowsiness increased, leg weakness developed, until the chickens no longer stood, but slept resting on their feet and legs, and later died. Death occurred usually from five to twenty-four hours after they had fed upon the rose chafers. Convulsions occurred in about five per cent of the deaths. Chickens that survived the twenty-four-hour period after eating rose chafers seldom died from the poison, though they did not seem altogether normal for several days afterward."

Saw-toothed grain beetle.—At least one case has been reported to the writer in which the saw-toothed grain beetle, *Oryzæphilus* (=*Sil-*

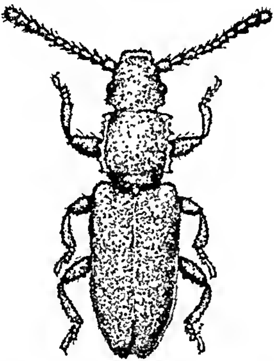

FIG. 38.—The saw-toothed grain beetle, *Oryzæphilus* (=*Silvanus*) *surinamensis*. × 33.

vanus) *surinamensis* (Linn.) (Fig. 38), of the family Cucujidae, invaded sleeping quarters, causing great annoyance to the occupants by nibbling at and crawling about on the body. The infestation, which lasted several days, was traced to the bathroom, thence out of the house through the yard and into an old barn under the stalls, where unquestionably grain from the manger had accumulated and where these beetles had been bred in great numbers. The dry California summer had pretty surely driven these insects to the bathroom for water, and the attack upon the occupants of the adjoining bedchamber was merely an incidental matter. However, it is interesting to note that an instance is recorded in Braun's *Parasites of Man*, viz., "Taschenberg records this beetle as having in-

vaded some sleeping apartments adjoining a brewery where stores were kept, and annoying the sleepers at night by nipping them in their beds."

Blister beetles.—Although numerous species of insects have vesicating properties, the most noteworthy are members of the coleopterous family Meloidae. Best known of these is the Spnnish fly, *Lytta vesicatoria* (Linn.) (Fig. 39). This species as well ns other blistering beetles is discussed in a later chapter.

Beetles as parasites.—Belonging to the family Platypsyllidae, indeed the only representative of this family, is the coleopterous parasite of the beaver, *Platypsyllus castoris* Ritsema (1869). This is a permanent, obligate parasite in all its stages. The eggs are deposited on the skin of

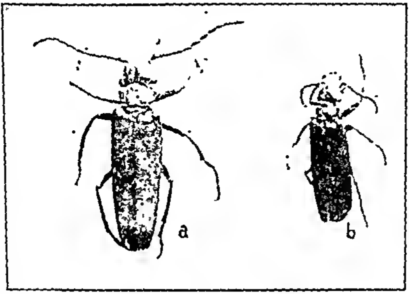

Fig 39—The Spanish fly, *Lytta vesicatoria*. *a* Female; *b*. *Male* × 2 1.

the beaver among dense hairs. It occurs on these animals in both Europe and North America.

Another family of Coleoptera, the Leptinidae, includes beetles which are parasitic on beavers, and certain rodents. The three known species are *Leptinus testaceus* Muller, on mice and shrews in Europe and North America; *Leptinillus validus* (Horn) on North American beavers; and *Leptinillus aplodontiae* Ferris, taken on *Aplodontia*, a genus of rodents known as mountain beavers peculiar to the Pacific coast (Ferris [7]).

Key to the Families of Coleoptera Referred to in this Chapter *

1 Antennae variable in structure but never lamellate... 2
Antennae with a club composed of from three to seven leaf-like segments

* Prepared by Dr. E. Gorton Linsley.

(lamellae); legs usually fossorial; tarsi five-segmented. (May beetles, June beetles, Cockchafers) .... *Scarabaeidae*

2. Anterior and intermediate tarsi five-segmented; posterior tarsi four-segmented 3
All of the tarsi either three-, four-, or five-segmented 4

3 Head as wide as prothorax; anterior coxal cavities open behind; body not heavily chitinized (Blister beetles) .... *Meloidae*
Head narrower than prothorax; anterior coxal cavities closed behind; body usually heavily chitinized (Darkling ground beetles) . *Tenebrionidae*

4. Elytra long, covering most of abdomen; abdominal tergites mostly membranous 5
Elytra short, exposing most of abdomen; abdominal tergites mostly chitinous 8

5. Fourth segment of tarsus distinct, free; antennae clavate, capitate or moniliform 6
Fourth segment of tarsus very small, fused with fifth segment; antennae usually filiform; body often brightly colored (Leaf beetles) . *Chrysomelidae*

6. Abdomen with five visible sternites.. 7
Abdomen with six visible sternites; tibial spurs large; antennae gradually thickened or clavate (Carrion beetles, Burying beetles) ... *Silphidae*

7. Anterior coxae conical, prominent; antennae moniliform; flat, non-scaly beetles (Flat beetles, Grain beetles)...................... *Cucujidae*
Anterior coxae globular, not prominent; antennae capitate or clavate; convex, scaly beetles (Leather beetles, skin beetles)....... *Dermestidae*

8. Wingless; eyes wanting or abortive................................ 9
Winged; the wings folding under the short elytra; eyes usually well developed; tarsi from three- to five-segmented .... *Staphylinidae*

9. Anterior coxae globular. (Beaver beetles).............. *Platypsyllidae*
Anterior coxae flat. (Rodent beetles).................... *Leptinidae*

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CHAPTER VIII

THE BUGS

ORDER HEMIPTERA

Bedbugs, Conenoses and Other Bugs

Order Hemiptera.—The Hemiptera comprise all the insects now included by some authors in two orders, Hemiptera and Homoptera. The order Hemiptera is divided into two suborders, viz.: (1) Heteroptera in which the first pair of wings (hemelytra) is thickened at the base and the distal overlapping portion is membranous, and (2) Homoptera in which the first pair of wings is of about the same thickness throughout.

The suborder Homoptera includes such important phytophagous families as the Aphidae (plant lice), Cicadidae (cicadas or harvest flies), Cicadellidae (leafhoppers), Membracidae (treehoppers) and many others of great agricultural importance, particularly many important vectors of plant diseases. These families include plant-feeding insects with piercing mouth parts, particularly leafhoppers and treehoppers, many of which have been reported as biting and sucking blood from human beings. Usinger[1] attributes this rather rare phenomenon of bloodsucking in the normally phytophagous groups of the Hemiptera to three influences, namely, the "stimulus of artificial light or other unusual conditions of the environment, the attractive qualities of exposed liquids, mainly perspiration, and hunger." He remarks further that this change, i e., "from plant feeding to bloodsucking, is not such a profound one as would at first be supposed. This is evidenced by a comparison of the composition of plant juices and blood and by the various plant-feeding groups, some members of which have adapted themselves to a predaceous habit or have shown their ability occasionally to suck the blood of mammals."

The Hemiptera-Heteroptera are the true bugs and are characterized by a jointed suctorial proboscis attached anteriorly, which, when not in use, is commonly flexed under the head. The winged members of this order normally have the wing covers, hemelytra (first pair of wings), thickened at the base and the distal overlapping portion more or less membranous. The true bugs are diverted into two divisions, (1) the Gymnocerata in which the antennae are conspicuous and capable of being moved freely in front of the head, e.g., *Cimex lectularius* Linn., the common bedbug; *Anasa tristis* (DeGeer), the squash bug; and *Triatoma*

45 days to 11 months, although the time is greatly influenced by temperature; there may be three or more generations a year under average conditions. Ordinarily they require six to eight weeks to reach maturity. Bedbugs are evidently sensitive to high temperatures; even a temperature of 100° F. with fairly high humidity will kill many of them. Activity ceases at about 60° F. At 60° F. to 65° F. bedbugs have lived for 136 days without food. Normally fed individuals can live for about a year under ordinary room-temperature conditions. The presence or absence of food influences their longevity greatly. Marlatt [5] has shown that bedbugs molt five times and that the minute wing pads, characteristic of the adult insect, make their appearance with the last molt. He also found that ordinarily but one meal is taken between each molt and one before egg deposition, and that an average period of eight days is required between moltings.

Methods of distribution.—Bedbugs, lice or any other organism, cannot originate spontaneously in filth as is believed by many; they must be introduced in some manner, either in the form of eggs, young or adults. Thus the introduction of one impregnated female might furnish the nucleus for a well-developed colony in a few months. Hence the best regulated household is not exempt from invasion, though cleanliness is the best preventive against the multiplication of any household pest.

Public conveyances are commonly means for the dissemination of bedbugs. As Smith [6] has well said, "I have seen them in railroad cars, trolleys, boats, omnibuses and carriages, and have noted them crawling on the clothing of well-dressed fellow passengers who probably did not bring them in." Furthermore, migration from house to house by way of water pipes, walls and the like is not at all unlikely when infested houses are vacated and the food supply is cut off. They are also easily carried in clothing, traveling bags, suit cases, etc.

Bedbug bites.—Persons "bitten" by bedbugs are differently affected; in some the bite produces marked swellings and considerable irritation, while in others not the slightest inconvenience is caused. (This is true in the case of flea bites and mosquito bites.) The bite, so-called, of the bedbug is produced by piercing organs of the hemipteron type already described. It is probable that the puncture of these stylets, unattended by contamination or specific poisons, would produce little pain. The welts and local inflammation are unquestionably caused by a specific poison secreted by the salivary glands and introduced in the act of feeding. The bedbug is able to engorge itself completely with blood in from three to five minutes. Although persons are usually bitten at night while in bed because of the normal nocturnal habits of the insects, they will bite freely in subdued light by day.

The fact that bedbugs are obliged to feed at least five times either

upon the same or a different host in order to reach maturity, has placed these insects under grave suspicion as possible vectors of disease.

Disease transmission.—In consequence of statements made by a number of authors that the bedbug is capable of transmitting plague and other septicemic infections, Nuttall (1899 loc. cit.) carried on a series of experiments with these insects. Mice were used in these experiments because they are very susceptible to the infections in question. He allowed the bugs to bite mice which had just died or were dying of anthrax, plague and mouse septicemia and then transferred them to healthy mice. Nuttall's experiments with anthrax are particularly instructive. Mice inoculated with anthrax died in from 18 to 24 hours, after which they were placed in glass-covered dishes and hungry bugs introduced. As soon as the bugs had sucked a little blood they were removed to test tubes by means of a small camel's hair brush and transferred to a shaved spot on healthy mice by inverting the tubes. Eight mice bitten by 124 infected bugs all remained healthy. Variations of this experiment gave similar results. It was found that the anthrax bacilli died in the stomach of the insect in 48 to 96 hours at 13° to 17° C., and in 24 to 28 hours at 37° C., and that the feces from the bugs contained living bacilli during the first 24 hours after feeding. In view of these experiments it may be concluded that infection through the *bite* of a bedbug either does not occur or is exceptional. That infection might occur if recently infected bugs were crushed while feeding and the punctured parts scratched, is to be expected. The feces may also be infectious. Nuttall [7] showed that spirochaetes survive in the bodies of these bugs for a period of six days at a temperature of 12° C. and a much shorter period (six hours) at 20° to 24° C. He, however, succeeded in transmitting the infection to a mouse, in only one instance, by transferring thirty-five bugs from an infected mouse to an uninfected mouse. Patton in 1907 [8] reported experiments with *Cimex hemipterus* (Fabr.) [*C. rotundatus* (Sign.)] in which he was able to trace the development of the Leishman-Donovan body of kala azar through all its intermediate stages up to the formation of the mature flagellates.

The bedbug would appear to be relatively unimportant as a disease vector, as indicated by the experiments cited above as well as many others performed by various investigators. In spite of the fact that bedbugs can experimentally transmit the pathogenic agents of plague, relapsing fever, leprosy and kala azar, there is no convincing evidence that the bedbug is the usual or even common vector of these or any other diseases at present known. The bedbug still remains, however, a potential menace to the public health.

Control.—The habits of these pests indicate in a measure the methods useful in their eradication in a given situation. The ease with which they

secrete themselves in very narrow crevices provides safety against anything but very penetrating materials. Metal bedsteads are easily kept free from the bugs, while the old-fashioned wooden bedsteads are more difficult to handle; however, the writer has seen some very bad infestations entirely eliminated by the use of kerosene applied by means of a tail feather from a fowl. The places where these pests hide during the daytime are usually near the sleeping quarters of the victims.

A widespread infestation of bedbugs will require a strenuous campaign. Where the infestation has reached such proportions as to include several rooms or even an entire building, the more rapid and effective fumigation methods are far preferable, requiring less labor and producing better results.

Hydrocyanic acid gas is perhaps the most effective of fumigating agents, but the greatest care must be exercised in its use, since the gas is deadly to all forms of animal life and extremely penetrating. Rooms above apartments in which this gas is being applied should not be occupied during or immediately after the process. Sparrows have been known to drop from the eaves of houses in which cyanide fumigation was going on. However, with proper precautions little danger is involved. The work should be done only by persons well informed about the use of this fumigant, preferably by a licensed pest control operator.

To prepare a room for cyanide fumigation, all wet or moist foodstuffs must be removed (dry materials such as flour, meal, bread, etc., need not be removed); if the house is occupied, *there must be no crevices leading from the room to be fumigated to occupied rooms.* It is best that the house should be vacated during the process—this need be for only a period of about 12 hours. Fumigation should not be undertaken when it is cold; a temperature of about 70° F. gives best results. If there is a fireplace in the room, this should be covered with a blanket or other covering. All crevices, such as occur around the doors and window sashes, keyholes, etc., must be tightly covered with strips of paper pasted in place with a very dilute flour paste, or as some have found, merely soaked in water. The cubic contents of the room must be estimated and sufficient ingredients provided to do the work. One ounce of potassium cyanide for every 100 cubic feet of space is necessary. To generate the gas, sulphuric acid and water must be used. The following proportions are needed for 100 cubic feet of space.

Potassium cyanide (98 per cent)	1 oz.
Sulphuric acid (about 66° Baume)	1 fluid oz.
Water	3 fluid oz.

or for 130 cubic feet of space:

Sodium cyanide	1 oz.
Sulphuric acid	1 fluid oz.
Water	2 fluid oz.

To proceed, place the water (in proper proportion) in a heavy two- to three-gallon earthen jar placed on thick folds of paper to catch spattered liquid, then slowly add the sulphuric acid (water always first, then the acid), lastly drop a paper bag containing the cyanide into the liquid, holding same at arm's length, and *immediately* beat a hasty retreat, carefully closing the door. In treating buildings with more than one floor the operator must always begin at the top and work downward. After the expiration of about five hours, open the windows from the outside and permit the room to "air" until the "peach kernel" odor has disappeared. The contents of the jar should be carefully disposed of.

Hydrocyanic acid gas may be generated more easily and with less apparatus by means of calcium cyanide. The dosage recommended is two pounds of Cyanogas G. Fumigant to 1,000 cubic feet. Weighing should be done outdoors to lessen danger and the material should be spread out thinly on several thicknesses of paper on the floor. The preparation of the rooms and the precautions above outlined must also be carried out in the use of this material. (Wakeland.[9])

To fumigate with sulphur, a very efficient method to destroy bedbugs and other vermin, the rooms are prepared as for hydrocyanic acid gas fumigation. All metal objects and fine, vegetable dyed fabrics must be removed, if possible; metallic objects should also be covered or, what is better, coated with vaseline. Sulphur, at the rate of four pounds to every 1,000 cubic feet of space, is placed in a shallow iron pot or skillet which is placed on bricks or stones in a tub in which there is a little water in order to prevent spilling out and igniting the floor. The sulphur is easily ignited by pouring over it a few ounces of wood alcohol (or grain alcohol) and then lighting it with a match. Fumigation must continue for at least two hours, when the doors and windows must be opened to ventilate the room before occupancy.

While sulphur fumes are extremely useful to combat insects and other animal life, such as rats and mice, the liability of bleaching fabrics and tinted paper and tarnishing metals must be taken into consideration.

Corrosive sublimate (1 to 500 solution) applied to bedsteads, floors, and other hiding places is efficient. The corrosive sublimate preparation should be applied with a mop. In case it is necessary to apply it by hand, rubber gloves should be worn to protect the skin. For mattresses, bedding and like materials, no treatment is superior to steam sterilization where the necessary facilities are at hand. By use of this medium the death of all stages is accomplished in a few moments if the steam has direct access to the insects. Where large bundles or piles of mattresses are placed in a steam sterilization chamber it is necessary to produce a partial vacuum followed by 15 to 20 minutes exposure to steam at 20 pounds pressure. Applying live steam by means of a suitable hose to bunks and crevices of bedbug infested bunk houses is very effective.

Infested bedsteads that can be "taken down" may be dipped in vats of corrosive sublimate solution, or if metal, fine results are obtained by heating all parts with a plumber's blow torch until the paint starts to blister, care being taken not to overlook the springs at the time of treatment.

Ordinary fly sprays, kerosene-pyrethrum, will destroy bedbugs and their eggs if contact is made with them. Power vaporizing machines as used by commercial pest control operators give excellent results, although hand sprayers may be used with good effect if the work is thorough.

Key to the North American Cimicidae *

1. Beak reaching beyond middle coxae Intermediate and hind coxae subcontiguous. Sides of hemelytra distinctly reflexed. Large bristles of body curved, rather broad, dentate only at their tips. Infests poultry in the Southwestern United States and Mexico *Haematosiphon inodora* (Duges)
   Beak not surpassing front coxae.. 2
2. Undersurface of head distinctly convex posteriorly, produced into a prominent tubercle on middle of posterior margin, the prosternum with anterior margin greatly arched to receive this. Tip of abdomen clothed with about fifty posteriorly directed, stiff, truncate hairs which are as long as width of an eye. Infests White-throated Swifts. California and Nebraska ....*Synxenoderus comosus* List
   Posterior margin of head less convex beneath, without such a tubercle. Last segment of abdomen without a distinct row of closely grouped hairs of uniform length as described above............................... 3
3. Metasternum broad. Middle and hind coxae widely separated. Scutellum subtriangular, the apex subacute Large bristles of body broad, curved, and denticulate on convex side.......................... 4
   Metasternum strongly compressed between middle coxae. Middle and hind coxae subcontiguous. Scutellum rounded posteriorly. Large bristles of body dentate only at tips.................................... 7
4. Front margin of pronotum shallowly concave. Pubescence long and sericeous. Last two antennal segments subequal in length. Occurs in the nests of Swallows throughout the United States *Œciacus vicarius* Horvath
   Front margin of pronotum widely and deeply concave. Pubescence of body relatively short except along the margins Third antennal segment longer than fourth. Genus *Cimex*.................................. 5
5. Sides of pronotum not widely dilated and not reflexed, fringed with sparse, nearly straight hairs. Hemelytra with apical margins distinctly rounded. Associated with man. Jamaica and Brazil *Cimex hemipterus* (Fabricius)
   Sides of pronotum widely dilated, broader than width of an eye, and densely fringed with backward curved hairs. Apical margins of hemelytra nearly straight, rounded toward inner angles.................. 6
6. Length of contiguous portions of hemelytra shorter than scutellum.

* Prepared by Dr. Robert L. Usinger for the purposes of this book.

Second antennal segment slightly shorter than third. Fringing hairs of pronotal margin shorter than width of an eye. Associated with man and almost cosmopolitan in distribution........*Cimex lectularius* Linnaeus
Length of contiguous portions of hemelytra longer than scutellum. ...ng hairs of ... the north- ... (Horvath)

7. Sides of hemelytra strongly reflexed. Pronotum a little less than half as long on median line as broad. Size three millimeters or less. Associated with Chimney Swifts. East and Middle West . .*Cimexopsis nyctalis* List
Sides of hemelytra not reflexed. Pronotum a little less than one-fourth as long on median line as broad. Size over three millimeters. In nests of Purple Martin. Colorado......*Hesperocimex coloradensis* List

Family Polyctenidae.—This family includes the relatively little known *bat bugs* which have led a very uncertain systematic existence since 1874, when Westwood founded the family Polyctenidae to receive these insects as aberrant Anoplura. Later they were placed with the Hippoboscidae, or louse flies (Waterhouse, 1879). The number of known species is quite small (less than a score of species), all bloodsucking ectoparasites of bats. They have a four-jointed rostrum (three-jointed in a single species from Africa), tarsi three-jointed and antennae four-jointed, eyes wanting, hemelytra short, the body commonly bearing ctenidia (combs). They are viviparous, the young being born at an advanced stage of development.

The two species known from this country have recently been described by Ferris and Usinger. One of these, *Hesperoctenes hermsi,* was taken recently on the free-tailed bat, *Tadarida macrotis* (Gray), in the Chisos Mountains, Texas, at an elevation of 6,200 feet by Mr. A. E. Borell. The other, *Hesperoctenes eumops,* has been taken at several localities in southern California on another free-tailed bat, *Eumops perotis californicus* (Merriam).

B. The Conenoses

Family Reduviidae

Family Reduviidae.—The Reduviidae are typical examples of the heteropterous Hemiptera. They are commonly known as conenoses, kissing bugs, and assassin bugs. There are said to be over 3,000 species belonging to the family which, because of the great variety of structures, is divided into fifteen subfamilies of which the Harpactocorinae is the largest, containing more than a third of all the species, and next in size is the subfamily Reduviinae. A very large percentage of the reduviids feed on insects, many of which are harmful, hence the family is in the main beneficial. A number of the species when handled protect them-

selves by biting, and a very few have developed a definite habit of sucking mammalian blood.

The head of these insects is more or less elongated or cone-shaped, giving rise to the term conenose; the head has remarkably free movement; the eyes are conspicuous; the ocelli, if present, are located behind the compound eyes; the sturdy, three-jointed proboscis is capable of being thrust forward, but in repose is curved beneath the head; the piercing stylets are capable of being extended far beyond the tip of the bent proboscis; the long, slender, four-segmented antennae are located in front of the eyes or on the border of the head; the prothorax is strongly developed; and most of the species are able to fly well.

Life history.—The rather large, conspicuous, more or less barrel-shaped eggs of reduviids are generally deposited in situations where the adults occur, i.e., the ground-inhabiting forms deposit their eggs on the ground; arboreal forms lay their eggs on leaves and stems; and house-inhabiting forms in dusty corners. The eggs of many of the species are illustrated by Readio,[10] who has also published a remarkably interesting work[11] dealing with the biology of the family.

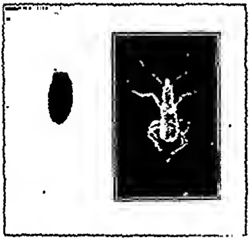

Fig. 41.—Egg (left) and larva (right) of a conenose, *Triatoma protracta*. × 4.4

The eggs are commonly deposited singly, also in small clusters, the total number per female varying considerably from a few dozen to upwards of 600. The incubation period varies from eight or ten days to nearly a month, depending upon the species and temperature. The newly hatched nymphs are wingless (Fig. 41). The usual number of nymphal instars is five, although Readio states that *Melanolestes picipes* (Herrich-Schaeffer) passed through only four. Overwintering varies considerably, some overwinter in the egg stage, others as adults, and still others as nymphs. In most cases there appears to be but one generation a year. The length of the life cycle of *Triatoma rubrofasciata* (DeGeer) was found by Neiva to cover 210 days and for *Mestor megistus* (Burm.) 260 days.

The alimentary canal of Triatoma protracta (Uhl.).—The alimentary canal of *Triatoma protracta* (Uhl.) according to Elson[12] is, as in other Hemiptera, divided into three regions, the fore-, the mid-, and the hind-intestine. (Fig. 12.) The fore-intestine comprises the pharyngeal duct, the pharynx and the oesophagus, and measures 4.3 mm. in length. The *pharyngeal duct* consists of a delicate tube which connects

the pharynx with the suction canal of the maxillae. It is a very short duct and difficult to distinguish from the pharynx. The *pharynx* may be considered as a highly specialized portion of the alimentary canal. It is a boat-shaped organ which measures on an average about 2 mm. in length and .3 mm. in diameter in the adult. The *oesophagus* is a delicate duct, measuring about 2 mm. in length and .1 mm. in diameter. Before reaching the proventriculus the oesophagus expands and forms the *proventricular vestibule.* The *mid-intestine* comprises the main portion of the alimentary tract and consists of the *proventriculus,* the *ventriculus* or stomach proper, and an elongated section. The *stomach* is a large sac which when filled with blood, occupies the greater portion of the body cavity and crowds the other organs to the sides and behind. When empty it is wrinkled, but when replete with blood it is smooth and pear-shaped. The mid-intestine-3 is a much coiled and narrowed portion of the mid-intestine; mid-intestine-4 is a short dilated portion. The hind-intestine is the shortest portion of the alimentary canal and comprises the *rectum.* This is a large muscular sac, capable of considerable distension, and usually containing fecal material. It is pear-shaped with the broadest part 2.5 mm. in diameter and its length 3 mm. At the termination of the mid-intestine there appears a circular whitish zone, the *rectal gland.* The *ampullae,* or enlarged bases of the *Malpighian tubules* (four in number and of equal size), form a rosette at this point. The Malpighian tubules are about twice the length of the insect and difficult to unravel.

The *salivary apparatus* consists of two pairs of glands, the principal and the accessory. The principal glands measure from 1 to 1.5 mm. in length and .8 mm. in diameter and are situated in the mesothorax, one on either side of the proventriculus. The spherical *accessory glands* (about .5 mm. in diameter) are located in the metathorax directly posterior to the principal glands to which they are connected with a duct.

Conenose bites.—Many of the species of conenoses inflict a painful bite when handled carelessly. Most notorious perhaps of all is the so-called "kissing-bug," *Reduvius personatus* (Linn.), a widely distributed species, particularly active in its biting capacity in the middle western and eastern United States. As early as 1899 Howard,[13] quoting Le Conte, writes as follows:

> "This species is remarkable for the intense pain caused by its bite. I do not
>
> which result from it will sometimes last for a week. In very weak and irritable constitutions it may even prove fatal."

The wheel bug, *Arilus cristatus* (Linn.), also has a bad reputation as a biter. Reporting on the bite of this species, Hall[14] states:

[illegible] and felt hot to the touch. In the course of a few [illegible] the [illegible] growths persisted for months, the largest slowly disappearing between six and nine months after the infliction of the bite. The injured finger remained warmer than the other fingers during this period, and, according to the patient's statement, still feels warmer than the other fingers, a year later. The development of pronounced cutaneous growths after a bite appears indicative of the action of some toxin as a stimulant irritant."

The symptoms produced by the bites of *Triotoma protracta* (Uhler) (Fig. 42a), a widely distributed Pacific coast species (which normally

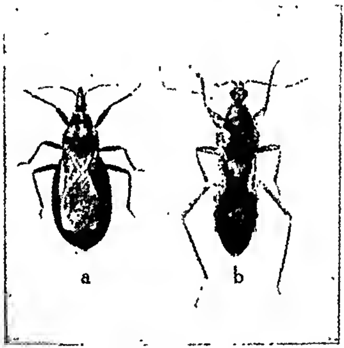

FIG. 42.—Members of the family Reduviidae. (a) *Triatoma protracta;* (b) *Rasahus thoracicus.*

occurs in the nests of wood-rats, *Neotomo* spp., and known as the "China bedbug"), are described by reporting physicians, viz.: "In a few minutes after a bite the patient develops nausea, flushed face, palpitation of the heart, rapid breathing, rapid pulse, followed by profuse urticaria all over the body. The symptoms vary with individuals in their intensity." Inquiries concerning these insects are most frequent during May and June. It frequently attacks sleeping individuals during the night.

The bloodsucking conenose or "Mexican bedbug," *Triotomo sanguisuga* (Lec.), inflicts a very severe bite, which, because of the uniform character of the resulting symptoms, supports the view that a specific venom is injected with the bite. The bite is said to result in "a burning pain, intense itching and much swelling . . . with red blotches and welts

all over the body and limbs." The effects of the bite may last for months; however, they usually disappear within a few days.

The "two spotted corsairs," *Rasahus biguttatus* (Say) and *Rasahus thoracicus* Stål (Fig. 42h), the former commoo in the southern states, Cuba and South America, and giving way to the latter in the Northwest and California, is the subject of many complaints. Howard (1899, loc. cit.) cites the following paper cooceroing "so-called spider bites" by Dr. A. Davidson in the Therapeutic Gazette of February 15, 1897, viz.:

He arrives at the conclusioo that almost all of the so-called "spider bites" met with io southern California are produced by no spider at all but by *Rasahus thoracicus* Stål. The symptoms which he describes are as follows:

"Next day the injured part shows a local cellulitis with a dark central spot; around this spot there frequently appears a bulbous vesicle about the size of a ten-cent piece and filled with a dark grumous fluid; a smaller ulcer forms underneath the vesicle, the necrotic area being generally limited to the central part, while the surrounding tissues are more or less swollen and somewhat painful. In a few days with rest and proper care the swelling subsides, and in a week all traces of the cellulitis are usually gone. In some of the cases no vesicle forms at the point of injury, the formation probably depending on the constitutional vitality of the individual or the amount of poison introduced."

The use of warm compresses of magnesium sulphate is recommended for the bites of cooenoses.

Chagas' disease (Brazilian trypanosomiasis).—Io 1909 Chagas [15] reported from Brazil an endemic human trypaoosomiasis prevalent among very young childreo and causing a high mortality. The acute disease is marked by a high fever lasting often several weeks. An enlargemeot of the lymphatics and especially of the thyroid is present in many cases, whence the name "parasitic thyroiditis"; this is, however, not a symptom of this infection according to authorities. In its chronic form, the disease is commonly maoifested by cardiac symptoms, motor paralysis, meotal weakness, idiocy and iofantilism. The disease is now knowo to occur in several other South American countries and in Panama.

The causative organism is *Trypanosoma cruzi* Chagas which occurs in the blood though sparsely during the acute stage of the disease and later in various tissues such as the heart, glandular tissue, and nervous system where the trypanosomes multiply. An importaot intermediate host is the conenose *Mestor megistus* (Burm.) [*Triatoma megista* (Burm.)], known as the "barbeiro," which is commonly found in native huts and is a fierce bloodsucker. Chagas found that the trypanosomes changed to round bodies (Leishmania-like) io a few hours after the bug fed on infectious blood and that a series of developmental changes

occur giving rise to infectious forms in the bug's feces in about eight days, infection taking place by contamination of the mucous membranes of the nose and mouth or the conjunctiva. The feces of infected bugs are highly infectious. Infection through the bite is not probable. The incubation period in the human is said to vary from 10 to 14 days after the insect attack. The bug is believed to remain infective throughout its life or as long as two years.

While Chagas believed the infection to be introduced by the bite of the bug, Brumpt [16] showed that infection results through the infective

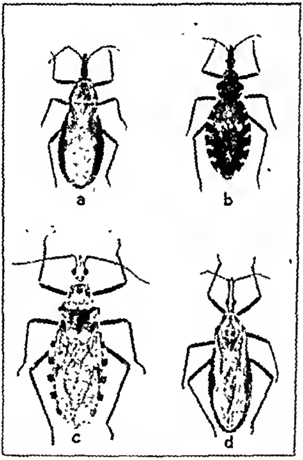

FIG. 43—Examples of Reduviidae: (a) *Triatoma protracta;* (b) *Triatoma sanguisuga;* (c) *Panstrongylus geniculatus;* (d) *Mestor pallescens.*

feces of the insect being deposited upon the skin of the host when the insect bites and inoculation results through the mucous membrane of the mouth, inasmuch as the conenose usually bites the face and lips of sleeping persons. Brumpt's experiments were with *Rhodnius prolixus* Stål, which defecates immediately after it has withdrawn its proboscis. Inoculation then results through scratching or rubbing the infective feces into the excoriated skin.

The list of reduviid species which are known to be vectors of *T. cruzi* includes the following, as shown by various investigators:

Mestor megistus (Burm.) (*Panstrongylus megistus*, Pinto = *Triatoma megista*, Neiva); *Triatoma sordida* (Stål) (*Eutriatoma sordida*, Pinto); *Triatoma uhleri* Neiva; *Psammolestes coreodes* Bergroth (lives in the nests of birds in South America); *Rhodnius pictipes* Stål; *R. prolixus* Stål; *Triatoma brasiliensis* Neiva; *T. chagasi* Brumpt et Gomes; *T. infestans* (Klug); *T. protracta* (Uhler); *T. rubrofasciata* (DeGeer); *T. sanguisuga* (Le Conte); *T. vitticeps* (Stål); *T. rubrovaria* (Blanchard) (*Eutriatoma rubrovaria*, Pinto); *T. flavida* Neiva (*Eutriatoma flavida*, Pinto). Four species are known to be vectors on the Isthmus of Panama, *Panstrongylus geniculatus* (Latreille), *Rhodnius pallescens* Barber, *Eratyrus cuspidatus* Stål and *T. dimidiata* (Latreille). *Triatoma dimidiata* (Latr.) has recently (1936) been discovered to be naturally infected with *Trypanosoma cruzi* in Panama by Rozeboom. [17]

The infection occurs in natural reservoir animals in South America such as armadillos, opossums, certain species of monkeys; cats and dogs also harbor the trypanosomes and evidently play an important rôle because of their domestic habits.

Recently Kofoid and Donat (1933) [18] have reported on the occurrence of South American trypanosomiasis of the human type in the wood rat, *Neotoma fuscipes macrotis* Thomas, in San Diego County, California, with *Triatoma protracta* (Uhler) the vector. Wood [19] (Fae Donat Wood) reporting later (1934) more fully states that the bloodsucking bug, *Triatoma protracta* (Uhler), and the wood rat, *Neotoma fuscipes macrotis* Thomas, are natural carriers of *Trypanosoma cruzi* in southern California. She was able experimentally to infect the following animals with the trypanosome: albino rats, albino mice, rhesus monkeys, a puppy, an opossum, the dusky-footed wood rat, and five species of white-footed mice. She also reports that the opossum and certain species of mice have been found in the wood rats' nests in the infected locality, hence may possibly also be carriers. In 1936 Kofoid and Whitaker [20] reported this infection in *Triatoma uhleri* Neiva from Tucson, Arizona. In 1938 Wood [21] reported an additional focus of infection in southern California.

It is of interest to note that Morishita (1935) [22] has conducted experiments with *Trypanosoma conorhini* Donovan regarded as non-pathogenic which resembles *T. cruzi* in its insectan phase, occurring commonly in the gut of *Triatoma rubrofasciata* (DeGeer) in Formosa. The natural vertebrate host has not yet been discovered.

Various species of ticks are capable of transmitting the infection to experimental animals; among these are *Amblyomma cajennense* (Fabr.), *Rhipicephalus sanguineus* (Latr.), *Ornithodoros moubata* (Murray),

and *Ornithodoros savignyi* (Audouin). *Ornithodoros turicata* (Duges) has recently (1937) been proved to be an experimental vector by Wheeler.[23] Further laboratory work now in progress will, no doubt, prove other species capable of transmission.

Key to Some Predaceous Reduviidae Likely to Be of Medical Importance *

1. Hemelytra with a quadrangular or discoidal cell at the base of the membrane. Subfamily Harpactocorinae.......................... 2

Hemelytra without a quadrangular or discoidal cell at the base of the membrane 4

2. Sides of mesosternum without a tubercle or fold in front. Basal segment of beak about as long as front portion of head. Tribe Zelini
Zelus socius Uhler
Zelus exsanguis (Stål)

Sides of mesosternum with a tubercle or fold in front of the hind angles of the prosternum First segment of the beak longer than front portion of head. Tribe Harpactocorini.................................... 3

3. Front femora but little, if at all, thickened, unarmed, a little granulated. Pronotum produced posteriorly over scutellum and with a high, median, tuberculate ridge. Form robust.........*Arilus cristatus* (Linn.)

Front femora thickened, spinose, densely granulated. Pronotum not produced or elevated as above. Form slender...*Sinea diadema* (Fabr.)

4 Pronotum constricted behind the middle. Front coxae with outer sides flat or concave. Subfamily Piratinae.............................. 5

Pronotum constricted at or before the middle. Front coxae not flattened, their outer sides convex. Subfamily Reduviinae............... 6

5 Apical portion of anterior tibia angulately dilated beneath, the spongy fossa being preceded by a small prominence. Hemelytra entirely black
Melanolestes picipes (H.S.)

Tibia not dilated, the spongy fossa elongate. Corium and membrane of hemelytra each marked with a yellow spot
Rasahus thoracicus Stål
Rasahus biguttatus (Say)

6. Antennae inserted on top of head between margins close to eyes. Antenniferous tubercles not projecting from sides of head. Beak stout, distinctly curved. Front of head turned downward. Tribe Reduviini
Reduvius personatus (Linn)

Antennae inserted in lateral or dorso-lateral margins of head. Antenniferous tubercles projecting slightly from sides of head. Beak slender and relatively straight. Head strongly produced anteriorly. Tribe Triatomini 7

7. Head very long and slender with antennae inserted near the apex
Rhodnius prolixus Stål

Head moderately long with the antennae inserted at or behind anteocular region.........................*Triatoma sanguisuga* (Lec)
Triatoma protracta (Uhl)

* Prepared by Dr. Robert L. Usinger for the purposes of this book.

Key to the Principal Families of Hemiptera-Heteroptera of North America which contain predaceous species *

1. Antennae at least as long as the head; either free or, in the Phymatidae, fitting in a groove beneath the lateral margins of the pronotum. Suborder Gymnocerata 6
   Antennae shorter than the head and nearly or quite concealed in a cavity beneath the eyes. Suborder Cryptocerata 2
2. *Ocelli present. Shore-frequenting insects. (Toad bugs)* Family Gelastocoridae
   Ocelli absent. Aquatic forms 3
3. Hind tarsi with indistinct, setiform claws (except in the minute, 3 mm. or less, Pleinae). Swim with ventral side upward (Back swimmers) Family Notonectidae
   Hind tarsi with distinct claws 4
4. Membrane of the hemelytra without veins. Abdomen without caudal appendages (Water creepers) .... Family Naucoridae
   Membrane of the hemelytra with distinct veins. Abdomen with caudal appendages 5
5. Caudal appendages of abdomen long and slender. Tarsi one-segmented (Water scorpions) .... Family Nepidae
   Caudal appendages of abdomen short, flat, and retractile. Tarsi two-segmented (Giant water bugs) Family Belostomatidae
6. Apex
   front 7
   Last segment of tarsi entire with claws of all the legs inserted at apex.. 8
7. Hind femora much surpassing apex of abdomen. Middle and hind coxae approximate, distant from front ones. (Water striders) Family Gerridae
   Hind femora scarcely surpassing tip of abdomen. Middle coxae (except in *Rhagovelia*) equally distant from front and hind ones. (Broad shouldered water striders) .... Family Veliidae
8. Head very long, at least as long as the three thoracic segments combined. Body linear. Legs and antennae very long and slender (Marsh-treaders) .... Family Hydrometridae
   Head shorter than pronotum and scutellum together 9
9. Antennae five-segmented. (Only members of the subfamily Asopinae are predaceous. These have non-raptorial front legs, three-segmented tarsi, and the first segment of the beak short, thick, and free) (Stink-bugs) .... Family Pentatomidae

   eight-segmented. These exceptions do not have the combination of characters listed under Asopinae) 10
10. Beak three-segmented 11
    Beak four-segmented 16
11. sternum with a the tip of the beak 12

* Prepared by Dr. Robert L. Usinger for the purposes of this book.

CHAPTER IX

THE LICE

A. The Sucking Lice

Order Anoplura

General characteristics.—The sucking lice have held various positions in their systematic relation to other insects, but within the past few years there is a strong tendency to place them in a separate order, Anoplura. A few taxonomists believe them so closely related to the biting lice that both groups of lice are placed in the same order, viz., Anoplura, with the Mallophaga (biting lice) reduced to a auborder and the sucking lice placed in the suborder Siphunculata. There is little to support the arrangement of these parasites under a suborder (Parasita) of the Hemiptera. For the purposes of this work the lice will be considered as belonging to two orders.

The members of the two orders, Anoplura and Mallophaga, resemble each other in many particulars but differ radically in their feeding habits, the former being bloodsuckers while the latter are feeders on scales and other products of the skin which are chewed by the insects. Wings are absent in both groups, the legs are in part adapted to cling to hairs and feathers, and the bodies are distinctly compressed. The Anoplura, or sucking lice, have a protrusible proboscis at the tip of the head; the Mallophaga, or biting lice, have a pair of distinct mandibles situated on the under side of the head. The biting lice are, as a rule, much more active than the sucking lice.

The Anoplura are inhabitants of mammals, while the Mallophaga inhabit both mammals and birds and in all cases are permanent ectoparasites limited largely to a specific host, very rarely except accidentally transferring to a different species. The entire life cycle is normally spent on one host.

Classification.—Students technically concerned with the sucking lice will need to consult the classical works of Ferris, particularly his systematic monograph appearing in eight parts, 1920 to 1935, Publications of Stanford University Press. Ferris places the known species of the order at about 200; these are arranged according to various authors in four families: (1) **Echinophthiriidae**, with body thickly covered with short stout spines and scales, antennae four- or five-jointed, spiracles

small; occurring exclusively on marine mammals, e g., *Antarctophthirus trichechi* (Boh.) on the Pacific Walrus, and *Echinophthirus phocae* (Lucas) on the seal; (2) Haematopinidae, body spines or hairs in rows, never with scales, tibiae with thumb-like process opposing the claw, eyes lacking, antennae five-segmented, e.g., *Haematopinus suis* (Linn.) on swine, and *Linognathus vituli* (Linn.) on cattle; (3) Pediculidae, the most important family of all from the public health viewpoint, since it includes the lice of man and other primates; (4) Haematomyzidae, heretofore included as a family of the Anoplura, has been placed by Ferris [1] in the Mallophagan suborder, Rhynchophthirina; it includes but the single species *Haematomyzus elephantis* Piaget of the elephant.

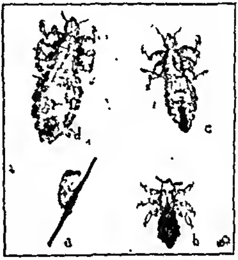

Fig 44.—Life history of the human head louse, *Pediculus humanus capitis* *a* Egg; *b* Nymph, *c* Male; *d* Female × 10

The lice of man and other primates.—The family Pediculidae, the only eye-possessing lice, includes the three genera, *Pedicinus*, *Pediculus* and *Phthirus*. The genus *Pedicinus* belongs exclusively, according to Ferris, to the *Cynomorpha* monkeys, and includes eight known species, *Pedicinus eurygaster* (Burm.) on *Macacus; Pedicinus longiceps* Piaget on *Pithecus; Pedicinus albidus* (Rudow) on *Macaca* (Barbary ape); *Pedicinus hamadryas* Mjöberg on *Hamadryas; Pedicinus patas* (Fahrenholtz) on *Cercopithecus patas; Pedicinus ancoratus* Ferris on *Presbytis; Pedicinus pictus* Ferris on *Colobus caudatus; Pedicinus obtusus* (Rudow) on *Semnopithicus maurus.*

The genus *Pediculus* is regarded by Ferris as including only three species, *Pediculus humanus* Linn, the head louse and body louse of man; *Pediculus mjöbergi* Ferris from *Ateles* apes; and *Pediculus schaffi* Fahrenholz, from the chimpanzee.

The genus *Phthirus* (also spelled *Phthirius*) includes the so-called crab lice, *Phthirus pubis* (Linn) of man; and *Phthirus gorillae* Ewing from the gorilla.

The human head louse, Pediculus humanus capitis DeGeer (Fig 44), is gray in color, but is said to vary according to the color of the hair and color of the host. (Murray.[2]) The male averages nearly 2 mm. in length and the female nearly 3 mm. This species occurs on the head, about the ears and occiput, but from reliable observations made by a number of

observers it may establish itself on other hairy parts of the body. In severe infestations the hair may become literally matted with eggs (nits), parasites and exudate from the pustules which originate from the louse bite. The term *plica palonica* is applied (Stiles) to the fetid mass, forming a sort of carapace (*trichoma*), in which fungus may develop, and beneath which myriads of lice may be found.

The number of eggs deposited by the female ranges from 50 to 150. These are glued to the hair and hatch in from 5 to 10 days, an average of seven days. Development is very rapid, three weeks usually covering the entire history from egg to egg.

Treatment for head lice.—Lice are easily disseminated, hence slight infestations may occur under the best of conditions, particularly among school children. However, the continued presence of lice on head or body is inexcusable. Personal cleanliness is the best safeguard. The mere use of water in washing the head is ineffective in destroying vermin present in the hair, and the nits are not easily destroyed even with chemicals. The simplest method of eradication is to clip the hair, catching the hair in a bag and burning it, and then applying a wash consisting of equal parts of kerosene and vinegar. Mixing the kerosene with olive oil lessens the possibility of irritation. The head should be thoroughly washed in an hour or two with hot water and plenty of soap. If nits are still found after this treatment, a second application should be made in a day or two.

The use of a fine comb dipped in kerosene gives good results. The oil coming in contact with the lice kills them, but the eggs are not destroyed, hence the combing must be repeated three times at intervals of one week in order to destroy the newly hatched young and thus prevent further propagation. The combings should be carefully disposed of by burning or dropping in kerosene to prevent further spread.

Washing the head with a 2 per cent solution of creolin is also effective if repeated as suggested above. Using a long towel wet with a 10 per cent solution of tincture of larkspur (Delphinium), as a turban about the head, is an effective method. The heads of children with long hair may be treated successfully in the following manner as described by Whitfield in the Lancet (Dec. 14, 1912). The child is placed on its back in a bed, with the head hanging over the edge, so that the hair falls in a basin resting on a chair. The solution to be used (phenol 12 grams and water 500 grams) is poured over the hair and carefully washed back and forth for a period of ten minutes until the hair is well soaked, particularly back of the ears and the nape of the neck. Afterwards the hair is drained, not wrung out, however, and is then put up with a towel or flannel cloth in turban fashion. After an hour the hair may be washed out or simply left to dry, when it will be found that all the pediculi as well as the ova have been destroyed.

The pubic louse, Phthirus pubis (Linn.) (Fig. 45), is easily recognized by its crab-like appearance. It measures from 1.5 to 2 mm. in length and is nearly as broad as long and is grayish white in color. It infests the pubic regions particularly but also the armpits and more rarely other parts of the body such as the mustache, eyelashes and eyebrows. The writer has *seen soldiers infested with this species of louse* from the ankles to the neck. These lice are remarkably stationary in their habits, often remaining attached for days at one point with mouth parts inserted into the skin. The pruritus caused by the bites of these parasites is very intense and a discoloration of the skin usually results if infestation continues over a longer period of time. The term *phthiriasis* may be employed to designate infestations of pubic lice, although the term *pubic pediculosis* is also used.

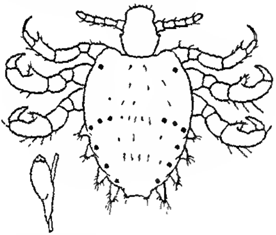

FIG. 45.—The pubic louse, *Phthirus pubis* Egg attached to hair

The female louse deposits its eggs on the coarser hairs of the body where the parasites occur. The number of eggs deposited per female is apparently quite small, although Nuttall[3] states that he would not be surprised to learn that 50 or more eggs may be layed. The incubation period seems to be from six to eight days After three molts the adult stage was reached in Nuttall's experiments in from 15 to 17 days, and the egg-to-egg period, 22 to 27 days.

Treatment for pubic lice.—The pubic lice are rather easily destroyed by rubbing the affected parts with a 10 per cent solution of tincture of larkspur, and repeating the application in about eight days. Washing the affected parts with hot vinegar to destroy the eggs may make a second treatment unnecessary

Shaving the hair of the pubic region, axillae, chest and legs, and then applying a kerosene-vinegar mixture followed by a bath with soap and

warm water has given good results. An objection to this method is the irritation produced by the growing hair, particularly to soldiers on the march.

Mercurial ointment is frequently applied but its use may cause a dermatitis, hence the following substitute is recommended, yellow oxide of mercury, 10 parts; salicylic acid, 1 part; and vaseline, 90 parts.

The body louse, Pediculus humanus corporis DeGeer (Fig. 46), is the common clothing louse which during the World War became known as the "cootie," also called the "grayback." Parasitologists now quite generally agree that there is no specific difference between it and the head louse, both are regarded as racial forms of *Pediculus humanus* Linn. Evidence concerning this agreement is most convincingly presented by Nuttall,[4] whose admirable treatises on lice and their relation to disease and control should be read by all students interested in the subject.

FIG. 46.—Human body louse, *Pediculus humanus corporis* × 15

Body lice infest the clothing where it comes in close contact with the body rather continuously, e.g., the fork of the trousers, armpits, the waist line, neck and shoulders. In his inspection of troops at delousing stations the author usually found lice on the underclothing, but all the nits were generally found in the seams of the breeches if present at all. After all clothing was removed lice were occasionally found on the body for which reason bathing and strong rubbing were insisted upon when possible to remove these stragglers. Eggs are undoubtedly by preference deposited on fibers in the seams of clothing as already mentioned. Nuttall and others have satisfactorily proved that the body louse may attach its eggs to the coarser hairs of the body, which may render it necessary to shave such parts in carrying on delousing operations.

Nuttall states that a female body louse may lay from 275 to 300 eggs, the average number laid per day being about 10 for 20 to 30 days. The incubation period varies from 4 to 8 days when eggs are kept near the body at about 35° C. Hatching, according to Nuttall, does not occur when the temperature reaches 22° C. or below; a favorable temperature being

attained at about 25° C. but with a slow development, lasting 16 days; and at 30° C. hatching was observed to occur in from 7 to 14 days, mostly in 11 to 13 days; at 38° C. hatching was slightly retarded and at 40° to 45° C. the eggs did not hatch. The effective zone for the egg stage is apparently from about 20° C. to 40° C. The optimum temperature for egg deposition is said to be about 32° C., ceasing at 20° C.

The young lice begin sucking blood at once on hatching from the eggs and throughout their development feed frequently both day and night, particularly when the host is quiet. Maturity may be reached in 16 days from the time the eggs are deposited. Unfed lice soon die; probably 10 days would cover the longest period of fasting. However, if fed, lice may live from 30 to 40 days.

The following instructive summary concerning temperature influences on lice is given in a lecture on the "Life History of the Human Louse," by Pierce,[5] June 17, 1918:

"In the absence of definite humidity data we may roughly describe the zones of climatic influence on the lice as follows The zone of minimum fatal temperatures for eggs is below 20° C (68° F) and for adults lies below zero centigrade (32° F) The zone of dormancy in adults extends from about −10° to 5° C. (14° to 41° F). The zone of sluggish movement without reproductive activity and with practically no digestive processes extends from 5° to 20° C. (41° to 68° F.). Digestion ceases at 12° C The zone of optimum activity lies between 20° and 40° C (68° to 104° F) with the optimum about 30° C. Practically all egg hatching occurs within this zone, as does all oviposition, practically all assimilation of food, and all normal activity From 40° to 44° C. the lice are wildly active, this zone represents one of exhaustion in which death of eggs occurs. Above 44° C (112° F) lies the zone of maximum fatal temperatures."

Relation to disease.—The presence of lice on any part of the body causes itching and is very annoying and may be designated as *pediculosis* That louse bites may produce certain systemic disturbances seems to be indicated in a report made by Moore[6]

"I started feeding about 700 to 800 twice a day Almost immediately a general tired feeling was noticed in the calf of the legs and along the shin bones, while on the soles of the feet and underneath the toes this tired feeling was so intense as often to prevent sleep until late in the night. An irritable and pessimistic state of mind developed. An illness resulted with symptoms very similar to grip and a rash similar to German measles was present, particularly over the shoulders and abdomen"

The skin of persons who continuously harbor lice becomes hardened and deeply pigmented, a condition designated as *vagabond's disease* or *morbus errorum*. Experiments conducted by Dewevre (1892) and others prove that lice may carry the causative organisms of both favus (*Acho-*

rion schoenleini Lebert) and tropical impetigo (*Diplococcus pemphigi contagiosi* Wherry). Nuttall (1898, loc. cit.) states that Dewèvre

"removed ten pediculi from a child suffering from impetigo and placed them on a healthy infant, which a few days later developed impetigo. The experiment was repeated several times with the same results. In a second series of experiments, he took scrapings from under the nails of children that had impetigo and placing them on artificially scratched places, reproduced the disease. Lastly he took pediculi from a child that was not affected with impetigo and placed them on a child that had the disease; removing them after twenty minutes, he replaced them on a healthy child The latter acquired the disease, as did fifty per cent of the children so experimented with. He claims the specific micro-organism adheres to the front legs especially, also to the hairs of the insect, and the latter carries them as bees do pollen. In the last set of experiments, he only allowed the pediculi to remain half an hour on the healthy head, but this was sufficient to produce infection."

The above typical example also illustrates the methods used to secure the experimental evidence of transmission.

Epidemic relapsing fever was shown to be louse borne by Mackie[7] in 1907. He records an outbreak of this disease among school children, in which 137 out of 170 boys and 35 out of 114 girls were attacked. Twenty-four per cent of the lice removed from the boys contained spirochaetes, *Spirochoeto recurrentis* Lebert (*S carteri* Manson), while only 3 per cent of the lice removed from the girls were infected. As the parasites increased in abundance among the girls, so also did the epidemic increase, and conversely as the parasites became less abundant among the boys, so also did the epidemic decrease. The spirochaetes were observed to multiply in the intestines of the lice and were found to be present in the ovaries, testes and Malpighian tubules. Mackie concluded that infection might be spread by the lice by regurgitating the spirochaetes into the wound produced by the bite. Later (1912) Nicolle, Blaizot and Conseil[8] failed to transmit the spirochaetes through the bites of infected lice, and found that the only reliable successful experiments involved the injectioo or subcutaneous inoculation of an extract of infected lice.

Based on experiments in which men and monkeys were exposed to bundreds of bites, Nicolle and his colleagues came to the conclusion that transmission is brought about by the introduction of spirochaetes received under the fingernails and on the finger tips from crushed parasites, which are inoculated into excoriated skin in scratching. They also fouod that the spirochaetes disappear and later reappear, only a few remaioiog in the insect's intestine up to 5 or 6 hours after infection, and none after 24 hours, but they reappear in the insect in from 8 to 12 days and are theo present in the general body cavity, none heing found in the alimentary canal. It was found that the spirochaetes were traosmitted to the offspring of infected lice. Chung and Feng[9] (1936) state that congenital

transmission of *Spirochaeta recurrentis* does not occur in lice. These authors also state that the salivary glands and Malpighian tubules of infected lice do not contain the spirochaetes, also that the feces of infected lice are not infectious. The gastric juice of lice is detrimental to *Spirochaeta recurrentis;* only about 1 to 5 per cent or less of the ingested spirochaetes gain access to the tissue and coelomic cavity where multiplication takes place, multiplication being by transverse division

The incubation period in the human is said to be from 6 to 8 days It is stated by Nuttall that a single infective louse, crushed upon the excoriated skin, has produced relapsing fever

Typhus fever.—Typhus fever, known also as tarbardillo (Mexico), Brill's disease (United States), jail fever or war fever, is a disease of ancient origin and wide distribution. Wherever human beings are concentrated in close quarters, especially in times of war and famine, this disease may become rampant. The disease is characterized by a high fever, backache, headache, bronchial disturbances, a congested face (designated also as a "besotted expression"), a brick-red mottled eruption which later spreads, forming brownish irregular blotches. This spotting led to the belief that tarbardillo of Mexico was identical with spotted fever of Montana, a fact that was proved to be erroneous by Ricketts, who contracted typhus fever and died from it during the course of his investigations. The experiments and observations by Nicolle and Ricketts and Wilder [10] indicate that the bedbug and the flea are not instruments of transmission. That rat fleas *are* instrumental in the transmission of endemic typhus from rat to rat in the United States was proved by Dyer et al. in 1932 (see Chapter XX). That the louse (*Pediculus humanus* Linn.) is probably the sole agent in the transmission of typhus fever from man to man was proved by Nicolle, et al.,[11] (1909, working in Tunis) and Ricketts and Wilder [12] (1910, working in Mexico). The latter found that *Pithecus (Macacus) rhesus* (Desmarest) can be infected with tarbardillo (Mexican typhus) invariably by the injection of virulent blood from man taken on the eighth to tenth day of fever, that the monkey may pass through an attack of typhus so mild that it cannot be recognized clinically and that immunity results Typhus was transmitted to the monkey by the bite of the louse in two experiments, the lice in one instance deriving their infection from man and in another from the monkey. Another monkey was infected through the introduction of the feces and abdominal contents of infected lice into small incisions. The causative microörganism of typhus is *Rickettsia prowazeki* da Rocha-Lima (loc. cit.).

The incubation period in the human is said to be from 10 to 12 days. The duration of the disease is said to be about 12 days in children, in which it may be comparatively mild, to 21 to 24 days in adults. The mor-

tality is said to range from 15 per cent to 30 per cent, but may be as high as 50 per cent to 75 per cent under war conditions.

After reviewing the evidence contained in the literature Nuttall[13] states in a summary that the virus of typhus occurs in the blood of the affected individuals and that blood collected on the third to the tenth day of the attack has been found virulent. Infection occurs through the bite of infective lice or through such lice crushed upon excoriated skin, and infection may result during seven to eleven days after the lice have fed on infective blood. If lice are crushed nine to ten days after an infective feed, or if their feces are collected three to six days after they have fed on infective blood, their contents and feces respectively are capable of producing infection if placed upon excoriated skin. It has not been determined how long lice remain infective when once contaminated and the evidence regarding the hereditary transmission of the virus is contradictory.

Endemic typhus fever is maintained in wild rats and transmission from rat to rat is effected by rat fleas, *Xenopsylla cheopis* (Roths.) and *Nosopsyllus fasciatus* (Bosc). The relation of fleas to typhus is discussed in a later chapter.

Trench fever.—Castellani and Chalmers in their manual of Tropical Medicine give a list of synonyms for Trench Fever, among them, Five-days fever, Volhynia fever, Pyrexia of unknown origin (P.U.O.), shank fever, His-Wernerische Krankheit, and Febris quintana.

"It is characterized by a sudden onset of fever associated with pains:—muscles and bones, particularly in the legs, with especial tenderness of the shins, and lasting twenty-four to forty-eight hours or longer followed by other attacks of fever of less and less severity, separated by apyrexial intervals of five days' duration more or less, and ending in complete recovery."

The causative organism of Trench Fever is believed to be *Rickettsia quintana*, so named by da Rocha-Lima[14] in 1916, confirming the earlier work of Toepfer.[15]

Two commissions, one British consisting of Byam, Carroll, et al., and the other American, consisting of Strong, Swift, et al., carried out very thorough investigations, during the World War, and the summary of the findings of the British commission follows:

"1. The whole blood from febrile trench fever cases, up to the 51st day of disease, when injected intravenously, is capable of reproducing the disease. The incubation period in such infections varies greatly—from 5 to 20 days.

"2. The virus as contained in the circulating blood is destroyed by the addition of distilled water in large quantities.

"3. The bites alone of infective lice do not produce trench fever.

"4. The excreta of infective lice when applied to a broken surface of skin do readily produce trench fever. The incubation period of such infections is remarkably constant and averages 8 days.

"5. The excreta passed by lice fed on trench fever patients are not infective till the expiration of not less than 5 days from the commencement of the feeding on trench fever blood, *thus indicating a development cycle in the louse or a* period during which the organism multiplies.

"6. Once lice are infective they remain so till at least the 23rd day from date of their infection.

"7. The virus of trench fever, as contained in infected louse excreta, is capable of withstanding drying at room temperature, exposure to sunlight, keeping for not less than 16 days, and heating to 56° C. for 20 minutes.

"8. 80° C. for 10 minutes destroyed the virus, which is therefore not a spore-bearing organism.

"9. The bodies of infected lice when crushed upon the broken skin are capable of producing trench fever. When lice become so infective remains to be determined.

"9a. Active trench fever blood equivalent to the content of 11 lice does not produce trench fever when rubbed into the broken skin.

"10. Infection probably does not take place by the mouth or by inhalation.

"11. The excreta of lice are not normally capable of producing trench fever.

"12. *Trench fever infected lice do not transmit the disease to their offspring.*

"13. There is a possibility of some attacks of trench fever being afebrile throughout

"14. The percentage of individuals naturally immune to trench fever is exceedingly small

"15. Old age is no bar to infection.

"16. Such immunity as results from an attack of trench fever is not permanent, and may only persist for so long as the individual shows evidence of the disease.

"17. Even as late as the 79th day of disease a patient's blood may remain infective, and be capable of infecting lice fed on such a patient while febrile.

"18. The *different varieties of trench fever result from differences in the* persons infected rather than in the source of infection."

Lice and taeniasis.—*Dipylidium caninum* (Linn), the double-pored dog tapeworm, is a common parasite of the dog and is occasionally found in humans, especially children. It measures from 10 to 14 inches in length, has long seed-like proglottids and an armored scolex, and has as its larval host the biting dog louse, *Trichodectes canis* DeGeer, as well as the dog flea, *Ctenocephalides canis* (Curtis), and the human flea, *Pulex irritans* Linn The cysticercoid stage has been experimentally produced in the louse by placing ripe crushed proglottids of the tapeworm on the skin of a dog infested with lice.

As has already been explained, the biting lice subsist on epidermal scales, skin exudations and other matter on the skin of the animal. This habit makes it comparatively easy for the louse to become infected by swallowing "eggs." The dog, on the other hand, readily infects itself by devouring the lice which irritate his skin.

Persons, particularly children, while fondling louse-infested dogs may easily become infected by accidentally swallowing lice which contain

bladder worms. This is more readily accomplished if the person is eating while handling the dogs.

Combating body lice (*delousing*).—The destruction of body lice and their eggs requires more than ordinary care as indicated by the preceding study of their life history and habits, and intelligent coöperation is essential.

To avoid becoming lousy several simple precautions are essential: (1) avoid contact with lousy persons and their effects; (2) avoid overcrowding; (3) bathe at least once a week with hot water using a heavy soap lather and rub dry with a rough towel; (4) complete change of underwear at least once a week, to dispense entirely with underwear is to invite lousiness; (5) do not sleep between blankets which were previously used by doubtful occupants of the bed and make sure that the bed linen is really fresh (under typhus-fever conditions, the above precautions must be supplemented by others, namely attendants must wear specially prepared protective clothing and that of patients should be placed at once in a vessel well oiled with kerosene, and the floors of the receiving rooms might well be oiled as an added protection); (6) where possibility of infestation exists, frequent inspection (at least once a week) of body and clothing is essential.

Much literature has appeared dealing with louse repellents and pediculicides and this subject is admirably treated in Nuttall's comprehensive work on "Combating lousiness among soldiers and civilians," in Parasitology, vol. 10, no. 4, pp. 411–588 (May, 1918), but little positive evidence concerning repellents is available—such materials as oil of eucalyptus, anise, and cloves, naphthalene and carbolic acid do have some repellent effect. N. C. I. powder, consisting of commercial naphthalene 96 per cent, creosote 2 per cent, iodoform 2 per cent, dusted over underclothing once a week has a killing effect, but it must be borne in mind that naphthalene is irritating.

Fumigation of clothing, persons to be properly bathed while this is being done, offers a quick means of louse destruction, but requires specially constructed sealed chambers (vacuum necessary in some cases) either stationary or portable. Fumigants do not as a rule destroy the nits, hence can only be regarded as temporary, and the treatment must be repeated periodically. Among the gaseous substances used for this purpose are the following: (1) ***hydrocyanic acid gas***, which according to Pierce (1918, loc. cit.) is generated in an air-tight generator using 2½ parts of sodium cyanide solution made by dissolving 4 pounds of sodium cyanide in 1 gallon of water, 1 part of sulphuric acid (commercial) and 1 part of water, and is piped into the fumigation chamber. Pierce directs: "Create 25-inch vacuum. Generate gas 5 minutes in generator. Wash into fumigation chamber. Break vacuum so as to fumigate in nor-

mal atmospheric pressure 25 minutes. Remove gas by producing 25-inch vacuum. Return to normal pressure. Open door slightly and run vacuum pump a few minutes." It must always be borne in mind that this is a very dangerous gas and must not be used by inexperienced persons. (2) *Carbon tetrachloride* does not require complicated apparatus and its use is described by Foster[16] viz.:

"A 10-gallon tin can such as is used for shipping liquid disinfectants was obtained. This can was 12 inches in diameter, 19 inches high, sheathed with a light wood covering, and weighed 5½ pounds. The top was cut out so that clothing could be introduced and removed readily In making the tests the complete clothing of a United States Army private, consisting of hat, olive-drab woolen blouse, olive-drab woolen breeches, leggins, socks, woolen underdrawers, woolen undershirt, and olive-drab shirt, was placed in this can, each article being firmly rolled up. A soiled shirt, badly infested with lice, was cut into four pieces. Each piece of the shirt was rolled fairly tightly and then further wrap[illegible] : of this material containi[illegible] breeches and placed near [illegible] live lice was tightly wrapped in the middle of the blouse and packed near the top of the contents The complete outfit of wearing apparel was placed in the tin and pressed down rather firmly, occupying a little more than one-half of the total space Several layers of filter paper were laid on top of the clothing, and on this paper 25 cc. of carbon tetrachloride was poured. The top of the can was covered by several thicknesses of toweling and a loose cover placed over this, the idea being to protect the can from the effects of drafts but not to seal it hermetically so as to permit some of the air to escape at the top when it was displaced at the bottom by the heavy vapor. At the end of two hours the can was opened, the package containing the lice-infested shirt was aired and examined All the lice were found to be dead and they did not revive when examined at various periods up to 24 hours after[illegible] r similar conditions, [illegible] and a half was not [illegible] as also found that a [illegible] kill the lice in two hours.

"These experiments were repeated in various ways with lice on pieces of cloth contained in test tubes open at both ends but fairly tightly sealed with cotton plugs These tubes were tightly wrapped in all the various articles of clothing and it was found that 25 cc of carbon tetrachloride, with exposure of two hours, was sufficient to kill all the lice . . . The garments were hung up and aired for an hour, after which no odor of carbon tetrachloride could be detected on them. . . . The tests were made at temperatures ranging from 68° to 72° F. . . . In considering the applicability of carbon tetrachloride as a delousing agent, the possible danger to human life must be borne in mind. The substance is said to be slightly more poisonous to human beings than chloroform."

(3) *Chlorpicrin* is highly recommended by Moore and Hirschfelder,[17] whose careful and comprehensive investigations concerning lice deserve much praise. The following account of their experiments with this gas

will also assist the student in understanding methods employed in this type of investigation. They write:

"In a study of the toxicity of a large number of chemicals it was found that chlorpicrin, or nitrochloroform (CCl_3NO_2), although quite volatile, possesses a very high toxicity. This high toxicity is due, in a large measure, to the ability of the chitin to absorb from the air even minute quantities of the chemical and to permit it to pass through into the insect's body. In studies dealing with the fumigation of grain and flour, chlorpicrin showed great penetration. Experiments were therefore conducted to determine its value in the fumigation of clothing to destroy lice and their eggs. Inasmuch as under field conditions only the simplest apparatus is available for the work, the fumigations were carried out in an ordinary galvanized iron ash can, without special efforts to make it air tight. Chlorpicrin of the desired quantity was poured upon the garments, while they were being packed in the can, thus insuring a more rapid evaporation and penetration. The results of these experiments show that to evaporate the chlorpicrin rapidly in order that it may penetrate all parts of the clothing and destroy the eggs of the lice within 30 minutes, a small amount of heat is necessary. Three one-liter flasks filled with water heated to 80° to 85° C. were found to answer the purpose In practice the box might be heated to 30° to 35° C. or hot stones might be used in the same manner as the flasks. Where no heat is available, a longer exposure is necessary. The active stages are more easily destroyed than eggs; hence in only two experiments were active stages used. They were placed in vials closed with gauze and the vials placed in pockets of the trousers in folds of the cloth, and in one case wrapped in three thicknesses of heavy underwear and placed in a leather ax case which was then strapped shut. The lice were in all cases killed.

"Inasmuch as chlorpicrin is used in gas warfare, a supply should be available on the fighting front. Owing to its poisonous nature, and its irritating effect on the eyes, nose, and throat, it would be necessary for the operator to use a gas mask Airing the clothing in the open for 3 to 5 minutes is sufficient to remove the chlorpicrin, after which the clothing can be worn.

"No bleaching or fading of colored fabrics was observed in a number of tests made with fabrics of delicate coloring, providing the chlorpicrin contained no impurities of chlorine or nitrogen peroxide. No injurious effect on leather was observed, but rubber is injured somewhat, although not as much as might be expected.

"The use of chlorpicrin is recommended as a means of delousing garments under conditions prohibiting the use of hot air or steam, since no particular apparatus is needed for the work. Chlorpicrin is superior to other chemicals recommended for fumigation since, on account of its extreme toxicity, high volatility and ability to penetrate through masses of clothing, a high tempera-

tages of

Laundry methods as a means of delousing have given good results when properly employed. Moore[18] reports that in the washing of rough cotton goods at 180° F. for 30 minutes, lice and their eggs are destroyed and that if by chance eggs should escape destruction in the washing process they would later be destroyed during drying in the hot-air tumbler. Woolens must be treated somewhat differently in order to avoid

shrinkage as shown by the work of Pierce, Hutchinson and Moscowitz,[19] viz.:

"1a. In the washer, run a current of live steam fifteen minutes, revolving cylinder every five minutes, and discharging water of condensation every five minutes Remove the garments and shake until almost dry. This requires only a few shakes.

"1b. Submerge in water at 165° F. for twenty minutes without motion, except a few revolutions every five minutes.

"2. Wash fifteen minutes at 131° F. in heavy suds and light load.

"3. Rinse three times, three minutes each, at 131° F

"4. Extract.

"5 Run in tumbler fifteen minutes, at a minimum of 140° F.

"We advise live steam (1a) or very hot soaking (1b) only in cases where there is no heated tumbler (5) available, or where the garments are suspected of being contaminated with very resistant spore-bearing bacteria.

"In other words, we recommend the usual laundry methods for the disinfection and disinsection, because of their added value of cleansing.

"There can be no doubt that the ordinary processes of the laundry will kill all lice and their eggs and probably all insect life We have proven that woolens can be treated with temperatures which will kill lice and bacteria, without undue shrinkage—that is, 131° F. Washing in *heavy* suds, with motion; 165° F soaking, without motion; live steam, without motion, except occasionally to remove water of condensation; or dry tumbling of wet garments, do not cause undue shrinkage of woolens."

Dry heat has long been used in destroying lice, such as ironing clothing with hot irons or singeing with a flame, also baking in an oven. The necessary killing temperature for both lice and nits is 60° C. (140° F.) for 20 minutes in case of dry articles. Various types of heat chambers have been devised, but in all cases there should be ample opportunity for fresh heated air to circulate in order to insure equal distribution of heat among the loosely hung garments.

Steam sterilization if available is a satisfactory method of delousing and it is not only disinsecting but also disinfecting. It has some disadvantages as compared with dry heat in that there is some danger from shrinkage, although this we have found to be slight when clothing is properly manipulated Unless nicely hung up it becomes badly wrinkled and certain stains (blood and excreta) become fixed by steam. Leather. rubber, felt, and books, of course, must not be subjected to steam sterilization. In the absence of permanent delousing stations at certain army camps the author organized a number of temporary stations using portable sterilizers (known as American Kinyoun-Francis Portable Disinfectors), circular type 40 inches in diameter and 96 inches long arranged in pairs side by side, each pair adjacent to a latrine with bath, one being used for blankets and underwear and the other for uniforms. About thirty-five men were handled per load every 30 to 35 minutes and each

station was in charge of a commissioned officer and five or six enlisted men as assistants. The following routine directions were in effect:

A. Directions to Men

1. Leave blankets at sterilizer before entering latrine.
2. Undress promptly and assist in determining whether or not you have vermin in your clothing or on your body, or have crab lice or head lice. It is to your interest to get rid of these now.
3. Place your uniform carefully over hangers provided for the same to avoid wrinkling.
4. Empty your pockets completely and do not send leather or rubber goods to the sterilizer.
5. Tie up your underwear, spiral leggins, socks and cap (unless it has leather band) into a bundle with belt, and attach identification disk.
6. Pass under shower and bathe thoroughly, using plenty of soap.
7. Dry with clean towel issued to you.
8. Receive sterilized belongings, dress and leave latrine, receiving blankets at sterilizer.

B. Directions for Sterilizer Unit

1. Follow directions for operation of sterilizer. (See directions posted on sterilizer.)
2. Hang uniforms in carriage carefully so as to avoid wrinkling and do not overcrowd.
3. With load ready, door properly closed, steam up in boiler and pressure in jacket, *produce a vacuum*
4. Vacuum of from twelve to fifteen inches held for about five minutes. (This is necessary to provide for penetration of steam and is essential to destroy lice if present)
5. Introduce steam in sterilizer chamber until fifteen to twenty pounds pressure is produced, and *hold* for fifteen minutes.
6. Allow steam to escape and again produce vacuum of about fifteen inches
7. Break vacuum and unload when zero is reached.
8. Return clothing promptly to men waiting in latrine.

Storage of garments likely to be infested with lice raises the question —How long will the lice and eggs survive? Since temperature plays an important rôle both in longevity and incubation, it may be said that lice can live without food for ten days at low temperatures (about 40° F.) and for shorter periods at higher temperatures (two to three days at about 85° F.); hatching may be delayed by low temperatures, e.g., Nuttall states 16 days at about 25° C. (77°F.) and the eggs do not hatch at 22° C. (71° F.) or below. It would apparently be safe to assume that dry storage for about three weeks would prove effective.

Live steam, where it is possible to secure it, is strongly recommended in the disinfection of bunk houses, bunks and other accessible structures where delousing operations (also bedbug control) are in progress.

Sucking lice affecting domesticated mammals.—The sucking lice

of the domesticated mammals belong to the family Haematopinidae and are arranged mainly under two genera, *Haematopinus* and *Linognathus*. *Swine* have one species of louse only, *Haematopinus suis* (Linn.) (*H. urius* Nitzsch) (Fig. 47). This is the largest representative of the entire group, measuring as much as 5 to 6 mm. in length, and is a cosmopolitan species. Next to cholera this louse is said to be the hog's worst enemy. These parasites occur chiefly in the folds of the skin on the neck, at the base of and inside the ears, along the belly and on the inner sides of the legs. According to Florence [29] hog lice feed readily on man but will not feed on guinea pigs. The same author summarizes the life history at 35° C., the organisms kept continually next to body in vials, as follows: incubation period of eggs (Fig. 48), 13 to 15 days, first molt after five to six days, second molt after four days, third and last molt after four to

FIG 47.—Hog louse, *Haematopinus suis*. × 7
FIG 48.—Nits (eggs) of the hog louse attached to the hair of the host One of the eggs has hatched. × 10.

five days, sexual maturity after three days, or a total of 29 to 33 days from egg to egg. It will be seen that this is a considerably longer time than is required for the life history of any of the biting lice, a matter to consider in the application of control measures.

Three species of sucking lice occur on *cattle*—*Linognathus vituli* (Linn.), commonly known as the long-nosed ox louse or "blue louse," measuring about 2 mm. in length and distinguished from the next species by its long nose and slender body; and *Haematopinus eurysternus* (Nitzsch) or the short-nosed ox louse, which is somewhat larger than the former and much broader in proportion; *Solenopotes capillatus* Enderl. has been redescribed by Bishopp [21] and shown to have a wide distribution in the United States and to be a serious cattle pest at times. It measures from 1.2 to 1.5 mm. in length and in general appearance apparently resembles the short-nosed ox louse. All three species show a tendency

toward attachment on the head, neck and shoulders of the host where the eggs are attached to hairs. The eggs of the short-nosed louse are said to be white, those of the long-nosed louse nearly black, and those of the *Solenopotes* pale yellowish. The incubation period ranges from 7 to 12 days according to various observers and the life history from egg to egg from 22 to 27 days. Lamson (loc. cit.) reports that the short-nosed ox louse lays from 35 to 50 eggs over a period of from 10 to 15 days. The larvae of this species mature in from 15 to 18 days.

Horses mules and asses are frequently infested more or less with one species of sucking louse, *Haematopinus asini* (Linn.) [*H. macrocephalus* (Burm.)]; it measures from 2.5 to 3.5 mm. in length; it resembles the hog louse except that the head is relatively longer and more robust. The lice are usually located at the base of the mane and forelock and root of tail. Hall (loc. cit.) reports that 22 out of 38 horses examined were infested with this species. The same author reports the incubation period for the egg to range from 10 to 19 days (eggs kept in Petri dishes at from 21° to 31° C.). It is quite probable that this species requires about the same time as the hog louse for the completion of its life history, i e, from 29 to 33 days from egg to egg.

Sheep are in some parts of the United States affected by the so-called foot louse, *Linognathus pedalis* (Osborn). The author has observed this species on sheep from California and Nevada, and Osborn has reported it from Iowa It occurs on the legs, especially in the region of the dew claws, but we have found that in heavy infestations it may actually invade the wool above the knee, and deaths have been reported as due to this louse This species measures about 2 mm. in length and as it is the only sucking louse likely to attack sheep in the above manner, its identity can be easily established. *Linognathus ovillus* (Neum.) is reported as the sucking louse of sheep in Scotland and New Zealand.

Goats often suffer heavy infestations of *Linognathus stenopsis* (Burm.). *Dogs* are commonly heavily infested with *Linognathus piliferus* (Burm.), and *rabbits* harbor *Haemodipsus ventricosus* (Denny).

Control of sucking lice of mammals.—Poorly fed animals, crowded pens and insanitary quarters are factors in the multiplication of lice, but the parasites may gain a foothold in spite of plenty of food, clean quarters and adequate space, hence the up-to-date stock farmer should not neglect to install a good dipping vat as a part of his equipment Although lice will not breed away from their host, they may drop off with hair and may remain alive for probably not over five days and the same animals after dipping or other animals of the same species introduced into quarters before the dropped lice have died, may become reinfested. Furthermore, the great majority of the ordinary dips do not destroy the eggs present at the time of treatment, hence a second dipping is usually

necessary after the young lice have hatched. This second dipping should be properly timed and in most cases should be done 16 to 18 days after the first. The author has found that concrete hog wallows containing water to which a film of crude oil is applied afford very satisfactory results in the control of the hog louse. The wallow should be shallow and built in the shade of a tree or otherwise protected from the sun so as to protect the pigs from oil burns.

Both the biting and sucking lice of cattle, horses and other animals may be controlled through the repeated use of *raw* linseed oil applied by hand, using a brush as already explained, but the animals must be kept out of the sun for 10 to 12 hours. In fact any of the effective dips may be successfully applied in this manner or also by means of an ordinary spray pump, provided the animal is given a thorough wetting. Among the dips used for lice are the following, (1) *kerosene emulsion*, prepared and used as described in the chapter on ticks; there is some danger from burns; (2) *arsenical dips* also prepared and used as described for ticks, its poisonous properties must be considered; (3) *nicotine dips*, containing 0 05 per cent of nicotine.

For the handling of smaller animals such as dogs, cats, monkeys, etc., we have found a small tub or pail very useful and a dip made of a 2 per cent solution of creolin. The water should be soft and lukewarm. Clear cool water should be at hand to bathe the face and eyes after the animal has been given a complete plunge. The use of a derris root dust as described for the control of biting lice is also recommended not only for smaller animals but cattle as well. There are some excellent dips, particularly coal-tar, on the market which should be used as directed, but there are also numerous dips that cannot be recommended.

B. The Biting Lice

Order Mallophaga

The common name "bird lice," often applied to the Mallophaga, is misleading as suggested, hence the term "biting lice" should be substituted.

Life history.—The breeding habits and life history of the members of the two orders of lice are quite similar. The eggs are attached to the hairs or feathers of the host (Fig. 49), near the base in each case, being glued fast by means of a cement secreted by the female louse. This fluid secretion flows around the base of the egg and the hair, featherlet, or fiber and quickly hardens to form a firm attachment. The eggs or "nits" are deposited singly over a period of two or three weeks, apparently corresponding to the length of life of the adult insect. The total number of eggs has not been worked out accurately for any one species of biting

louse, though Lamson [22] gives thirty-five to fifty as the number for the "short-nosed" cattle louse (Anoplura).

Injury done by biting lice.—The injury done by the biting lice is largely restricted to poultry, although some trouble may result when mammals are badly infested. The injury is largely due to irritation or itching caused by the creeping insects and their incessant gnawing at the skin. This irritation causes the host to become exceedingly restless, thereby affecting its feeding habits and proper digestion, resulting in unthriftiness. Egg production in fowls is greatly reduced and development retarded. A lousy flock of poultry is not a good investment. When lice are abundant uncleanliness and overcrowded conditions usually exist.

Classification.—The biting lice (Mallophaga), of which there were about 1,400 species [23] in 1916, may be divided into two suborders with 1,257 species according to Kellogg [24] in 1908: (1) Amblycera with short, clavate or capitate, four-segmented antennae, concealed in shallow cavities or under side of head; four-segmented palpi, mandibles, horizontal; and (2) Ischnocera, with short, slender three- or five-segmented, exposed antennae, no palpi, mandibles vertical.

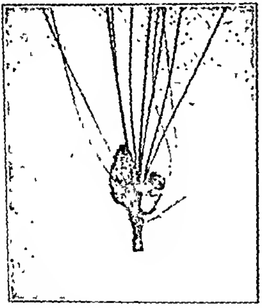

FIG 49—Eggs of biting lice (Mallophaga) on feathers of a bird

Kellogg divides the Amblycera into two families, viz.: (1) Gyropidae—tarsi with one claw, infesting mammals only, e.g., *Gyropus ovalis* Nitzsch and *Gliricola porcelli* (Linn.), both of the guinea pig; and (2) Liotheidae—tarsi with two claws, infesting birds mainly, e.g., *Menopon pallidum* Nitzsch, the "shaft louse" of chickens, and *Trinoton luridum* Nitzsch of ducks. He also divides the Ischnocera into two families, viz.: (1) Trichodectidae—antennae three-segmented, tarsi with one claw, infesting mammals only, e.g., *Trichodectes bovis* (Linn.) (*J. scolaris* Nitzsch) of cattle, and (2) Philopteridae—antennae five-segmented, tarsi with two claws, infesting birds mainly, e.g., *Goniodes stylifer* Nitzsch, the large turkey louse, and *Lipeurus caponis* (Linn.), the "wing louse" of chickens.

The life history of a biting louse.—One of the most outstanding life history studies of a biting louse was made by Martin [25] on the pigeon louse, *Columbicola columbae* (Linn.) (*Lipeurus baculus* Nitzsch). She

found that as many as sixty white, opaque eggs are attached to a single feather. The incubation period at 37° C. was normally from three to five days; at 33° C. it ran from nine to fourteen days. At the latter temperature the nymphs always died in from one to six days. There are three instars, each requiring on an average slightly less than seven days, making a total of between 24 and 25 days for the complete life cycle. At 37° C. the adults live usually from 30 to 40 days, the longest time being 51 days. Temperature is the chief factor in determining the length of the life cycle as well as the survival of the young.

Lice infesting domestic fowls.—More than forty species of lice are said to occur on domestic fowls of which seven species are commonly found on chickens. Losses due to poultry lice are most evident among

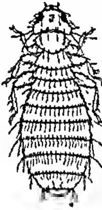

Fig. 50.

Fig. 51.

Fig. 52.

Fig. 50.—The common shaft louse of poultry, *Menopon pallidum*
Fig. 51.—The large hen louse, *Goniocotes abdominalis* × 10
Fig. 52.—A turkey louse, *Goniodes stylifer* × 14

the young birds, but heavy infestations on older fowls result in loss of weight, lowered egg production and lowered vitality. Although other maladies may present similar symptoms, infested fowls are droopy, lower the wings, present an unkempt and ruffled appearance and suffer from diarrhea. The commoner lice of chickens are (1) the "body louse" (*Menopon biseriatum* Piaget), a rapidly running species occurring on all parts of the fowl but mainly on the body where it crawls around on the skin; it is light yellow in color and about 2 mm. in length; it lays its eggs in large clusters, particularly on the small feathers below the vent; the egg stage requires about a week and maturity is reached in about two weeks thereafter; (2) the "shaft louse" (*Menopon pallidum* Nitzsch) (Fig. 50), which resembles the body louse very closely but is smaller in

size, and occurs mainly on the shafts of the feathers; it is said to gain its nourishment from barbs and scales of the feathers and is therefore not as irritating as the former species; according to Bishopp and Wood [26] it does not occur on young chickens and deposits its eggs singly, at the base of the feathers between the main shaft and the after shaft; the life history appears to require a somewhat longer time than the former species; (3) the "head louse" (*Lipeurus heterographus* Nitzsch), a dark grayish species about 2 mm. in length, infesting the head and neck of young chickens on which it is most injurious; it deposits its eggs singly on the down or small feathers about the head and requires about the same time for complete development as the first species mentioned; (4) the large hen louse or "blue bug" (*Gomocotes abdominalis* Piaget) (Fig. 51), about 3 mm. in length, broad with rounded head and smoky gray in color; it is generally distributed over the body and easily recognized; (5) the "wing louse," *Lipeurus caponis* (Linn.) (*Lipeurus variabilis* Nitzsch), also known as the "variable louse," a long slender species about 2 mm. in length; the margins of the head are black, the head is large, rounded and the general appearance is sufficiently distinct to separate it from all the other species; (6) the "fluff louse" (*Goniocotes hologaster* Nitzsch), a very small and broad species about 1 mm. in length, pale in color and seldom abundant; (7) the "brown louse" (*Goniodes dissimilis* Nitzsch), reported for the southern United States by Bishopp and Wood; it is described by them as somewhat smaller than the large hen louse and reddish brown in color and found on the feathers of the body.

Turkeys are commonly infested with the large (3 mm. long) *Goniodes stylifer* Nitzsch (Fig. 52) which has the posterior angles of the head extended backward into long projections terminating in stylets or bristles. Another louse found on turkeys is *Lipeurus polytrapezius* Nitzsch, a long slender species measuring from 3 to 3 5 mm. in length. *Ducks* and *geese* harbor a rather small-sized species, *Docophorus ieterodes* Nitzsch, measuring about 1 mm in length in which the head is curiously expanded and rounded in front and is a darkish red and the thorax is red also with darker bands; another species infesting ducks and geese is *Lipeurus squalidus* Nitzsch (Fig. 53), which is about 4 mm. in length, head longer than broad, very slender and light yellowish in color. Another long species infesting ducks (4 mm.) is *Trinoton luridum* Nitzsch, dark grayish in color with triangular head about as long as broad. None of these species appears to become abundant enough to be of any great consequence. The common lice of the swan are *Docophorus cygni* Denny, about 1 mm. in length; "in color the head, thorax and legs are bright reddish brown while the abdomen is white in the center and dark brown at the sides, the brown occupying hard plate-like portions at the side of each segment"; and the extremely large and common *Ornithobius bu-*

cephalus Piaget (4 mm. long). The latter is conspicuous because of its size; the body is white and quite transparent.

Pigeons are often abundantly infested with *Columbicola columbae* (Linn.) (*Lipeurus baculus* Nitzsch), a very slender species measuring about 2 mm. in length; *Goniodes damicornis* Nitzsch, a broad brownish species about 2 mm. long, and *Goniocotes compar* Nitzsch, about 1 mm. in length, whitish in color with a rounded head in front. Guinea fowls are said to harbor *Goniodes numidianus* Denny, *Lipeurus numidae* Denny and *Menopon numidae* Gieb.; pea fowls, *Goniocotes rectangulatus* Nitzsch, *Goniodes falcicornis* Nitzsch and *Menopon phaeostomum* Nitzsch; pheasants, *Goniocotes chrysocephalus* Gieb., *Goniodes colchicus* Denny, *Lipeurus heterographus* Nitzsch and *Menopon fulvomaculatum* Denny.

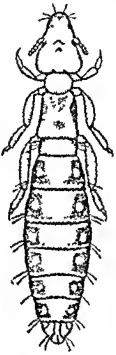

FIG 53.—A duck louse, *Lipeurus squalidus* (Redrawn after Osborn) × 10

Control of poultry lice.—No remedy has given such uniformly satisfactory results in the control of the lice of all kinds of domesticated birds as has sodium fluoride (NaF), aparently first used against these parasites by Bishopp and Wood in 1917. This remedy has been very carefully tested with excellent results in the great poultry centers of California Sodium fluoride can be obtained in two forms, a white powder or commercial form (90 to 98 per cent pure) and in fine crystals or chemically pure For louse control the former more finely powdered form is preferable. It retains its efficiency almost indefinitely if kept in a dry place in stoppered bottles or cans One application generally will destroy all lice present. It may be applied in three ways, viz, the pinch method, dusting and dipping.

The *pinch method* consists of placing on the skin of each fowl aprpoximately ten "pinches" (amount held between thumb and forefinger) of the commercial sodium fluoride distributed on the breast, each thigh, below the vent, on each side of the back, on the neck, on the head, and finally one sprinkled on the underside of each outspread wing. The birds, when treated, should be held over a shallow pan or newspaper in order that the excess of the chemical may be saved.

Dusting.—The powdered sodium fluoride is sometimes mixed with three or four times its bulk of flour or talc and applied with a large shaker, ruffling the feathers of the bird as the chemical is applied. This procedure is not as economical of material or as efficient as the pinch method and the excess of chemical in the air is irritating to birds and operators.

Dipping in sodium fluoride solution is rapidly becoming a standard method of treatment among a large group of producers that have overcome the poultrymen's prejudice against wetting their birds. In California, birds may be dipped safely in almost every month of the year by choosing a warm day with little wind and completing the operations an hour or two before sundown in order that the fowls may dry thoroughly before roosting for the night. The solution should be prepared in a wooden container, avoiding contact with galvanized iron. The ordinary wooden wash tub is excellent for this purpose. One ounce of the commercial sodium fluoride or two-thirds of an ounce of the chemically pure crystals should be dissolved in each gallon of tepid water. The best method for dipping the birds is to hold them with the left hand by both wings. They are then placed feet foremost in the warm dip and submerged until only the head remains above the surface. They should be held in this position from 20 to 25 seconds while the feathers are being ruffled to permit penetration of the liquid. Just before removal the head should be ducked under the surface. The birds should be held above the dip for two or three seconds to allow them to drip before releasing them. One hundred birds will use up approximately five gallons of dip, on which basis material should be available at the start of operations to keep the dip replenished.

The dipping method kills all lice immediately, but where the chemical is applied as a powder three or four days pass before elimination is complete. If the birds are caught and handed to the operator from 100 to 125 birds an hour can be treated by dipping or dusting and approximately 60 to 75 per hour by the "pinch" method

Other methods.—The very fact that poultry wallow in dust whenever available indicates a means of partly controlling the bird lice. Special box wallows, conveniently placed, broad and deep enough so that there will be room for several birds at a time, should be partly filled with fine road dust or ashes with the addition of a quantity of tobacco dust in the proportion of about six parts of the former to one of the latter. It is quite desirable to add a few handfuls of sulphur. The finer the dust the better, since it is believed by some that the dust particles enter and clog up the breathing pores of the lice. However, it is more probable that the agitation caused by the birds wallowing in the dust dislodges many of the lice and they are thus lost in the shuffle. A very good louse powder for dusting birds by hand is prepared by mixing gasoline, 3 parts, and carbolic acid (about 90 per cent pure), 1 part, and stirring into this mixture enough plaster of Paris to take up the moisture. When preparing this mixture, it must be borne in mind that the gasoline is highly inflammable and that the carbolic acid is poisonous and injurious to the skin. Pyrethrum powder or buhach (fresh) applied to the hen directly by means of

a duster is also a good remedy, as is dusting with flowers of sulphur. Naphthalene flakes in the nests and naphthalene nest eggs, while fairly effective, are injurious both to the hens and the eggs. Dipping chickens in a 2 per cent solution of chloriae is recommended by some. After a flock of birds has been freed from lice all new acquisitions should be treated before being placed with them.

We have found powdered derris root applied as a dust or as a dip, oae-fourth ounce to a gallon of water, to be effective. This method is also described by Wells, Bishopp and Laake.[27]

The application of 40 per cent nicotine (Black Leaf 40) to the roosts in a thin layer with a brush or swab before the birds go to roost gives excellent results. The treatment should be repeated at an interval of ten days to kill the lice which have hatched from eggs on the birds. It is recommended that the application be made when the weather is calm. Apparently this treatment acts as a fumigant.

Biting lice of domesticated mammals.—The biting lice of the domesticated mammals are for the most part rather easily identified by their presence on a given host, as commonly not more than one species of Mallophaga is found on each species of mammalian host. *Cattle* are often heavily infested on the withers, root of tail, neck and shoulders with *Trichodectes scalaris* Nitzsch (Fig. 54), a little reddish yellow louse about 1½ mm. in length, definitely marked with transverse bars (ladder-like) on the abdominal segments The white eggs are deposited on the hairs of the host and the entire life history from egg to egg requires about three weeks. The lice are most numerous on the animals during dry, cold weather when the hair is long. Although the biting lice do not irritate the cattle as much as sucking lice, the following noteworthy observation is made by Imes:[28]

"When present in large numbers, however, they often form colonies or groups around the base of the tail, over the withers, and on other parts of the animal, and produce lesions resembling those of scab These lesions vary in size from that of a 25-cent piece to 4 or 5 inches in diameter The skin over these areas appears to be raised and ringworm may be suspected, but when the lesion is manipulated the scarf skin falls off, exposing the lice grouped on the raw tissues beneath. Under such conditions the irritation is very great and the damage to the animal may be fully equal to that caused by scab"

Horses, mules and *asses*, but horses more particularly, when poorly or irregularly groomed may suffer from two species of biting lice, *Trichodectes parumpilosus* Piaget and *Trichodectes pilosus* Giebel, of which the latter according to Kellogg and Ferris[29] has not been reported from North America although it is reported by Hall[30] on horses in Michigan. *Trichodectes parumpilosus* Piaget is described by Osborn[31]:

"The head is decidedly rounded in front, the antennae inserted well back, so that the head forms a full semicircle in front of the base of the antennae. The

abdomen is more slender and tapering than in *scalaris*. . . . The color is much as in the allied species, the head, thorax and legs being a bright reddish brown, or chestnut, and the abdomen of a dusky yellowish color, with about eight transverse dusky bands occupying the central or anterior portions of the segments and extending from the middle line a little more than halfway to the margin. They are hardly as conspicuous as in *scalaris*."

T. pilosus Gieb. is a smaller species and the antennae are inserted well forward, almost on a line with the anterior border. Hall states that these "lice give rise to itching, and the results from this are often surprisingly unpleasant. A barn full of horses may become a pandemonium as a result of lice The itching animals attempt to relieve the itching by rubbing and biting, other animals start to kick, presently the kicking becomes

FIG 54

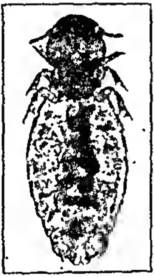

FIG 55

FIG. 56

FIG 54—The biting ox louse, *Trichodectes scalaris* × 26.
FIG 55—Biting louse of the Angora goat, *Trichodectes hermsi*. × 22.
FIG 56—The biting dog louse, *Trichodectes canis*. × 35

general and there is a resultant clamor and din, with a substantial element of danger to the horses and attendants." The life history is about the same as for the biting cattle lice.

Sheep may at times show severe infestations of *Trichodectes ovis* Linn. (*T. sphaerocephalus* Nitzsch). This species is about 1.5 mm. in length, the head being somewhat rounded and as long as broad and reddish in color; the abdomen is whitish. Because of extensive dipping operations against scab this louse has seldom had an opportunity to thrive, but we have observed that when scab had disappeared and consequently no dipping was done, the biting lice appeared in troublesome numbers.

Goats are very commonly enormously infested with biting lice. Sev-

eral species from goats have been described, about which there is still some confusion, but the common species is *Trichodectes caprae* Gurlt (*T. climax* Nitzsch). The author has found Angora goats to be heavily infested with *Trichodectes hermsi* Kellogg and Nakayama (Fig. 55), which resembles *T. penicillatus* Piaget, which in turn is said to be a synonym of *T. limbatus* Gerv., of *T. crassipes* Rudow and *T. major* Piaget. The irritation produced by the lice particularly on Angora goats causes the animals to rub or bite themselves so much that the mohair is matted and pulled out, resulting in considerable loss The individual hairs are weakened by the gnawing of the lice.

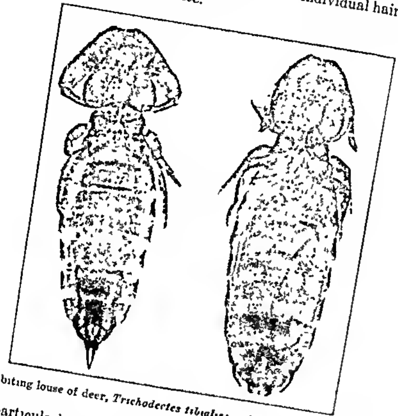

FIG 57.—A biting louse of deer, *Trichodectes tibialis*; male, left, female, right × 31

Dogs, particularly puppies, may suffer much irritation from a small biting louse, *Trichodectes canis* DeGeer (*T. latus* Nitzsch) (Fig 56). It is a broad, short species, measuring about 1 mm. in length. The author has also taken biting lice from a dog in Berkeley, Calif, which were described as *Heterodoxus armiferus* by Paine.[32] As this genus is said to be restricted to the kangaroo the incident is interesting The latter species is now considered as a synonym of *Heterodoxus longitarsus* Piaget.

Cats may become heavily infested with *Trichodectes subrostratus* Nitzsch. *Guinea pigs* commonly harbor two species, *Gyropus ovalis* Nitzsch and *Gliricola porcelli* (Linné) (*Gyropus gracilis* Nitzsch). The

llama harbors *Trichodectes breviceps* Rudow. *Trichodectes tibialis* Piaget (Fig. 57) is exceedingly abundant on California deer.

Control of biting lice on mammals.—Sodium fluoride as employed for control of lice on poultry (dusting method) has proved effective in the destruction of the biting lice on cattle, horses, goats, sheep, dogs, cats (light treatment) and guinea pigs. Bishopp states that "a high degree of effectiveness (90 to 100 per cent destruction) may be obtained by applying the sodium fluoride with a dust gun to the flock in a pen as the goats are driven through a chute. It does not seem to be necessary to drive the dust into the mohair especially and only a small amount—about one-third ounce per head—is necessary."

The following suggestion by Lamson (loc. cit.) for the treatment of cattle lice in general is particularly noteworthy:

> "Of the many different measures for the control of lice on *dairy cows* and [illegible] from the standpoint of economy [illegible] ing the skin [illegible] ch the cow. It has no poisonous properties. At the same time it is a logical remedy, as the lack of oiliness in the skin of the cow is a fundamental reason for her being lousy. Linseed oil can be put on at the time taken for grooming or cleaning the cows, thus doing two things in [illegible] From four to five cows can be treated with a pint [illegible] times. Raw linseed oil can be best ap[illegible] equal length Do not rub the skin too vigorously when applying the oil. Do not allow the animals that have been treated to go out in the strong sunlight until at least twelve hours after applying the oil. Do not exercise the animals after the treatment. Do not use the boiled or refined linseed oil."

Linseed oil as already suggested is effective against both kinds of lice, while sodium fluoride is useful against biting lice only. As a rule effective standard dips, made of kerosene, nicotine, arsenic, cresol, etc., as recommended in this chapter, will give good results for all lice, but because of the simplicity of application and low toxic action of sodium fluoride to domesticated animals and man, it is worth while determining whether the lice are Mallophaga or not.

It has lately been found by Wells, Bishopp and Laake (loc. cit.) that a dust compound of derris root [supposedly *Degnelia* (*Derris*) *elliptica*] and a carrier such as flour (equal parts) is effective against both biting and sucking lice.

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CHAPTER X

GNATS (Exclusive of Mosquitoes)

Order Diptera

General characteristics.—The medical entomologist must be well versed in the Diptera,* because to this order belong many of the vectors of the world's most important diseases, notably malaria, yellow fever, dengue, and African sleeping sickness. The Diptera commonly designated as "the flies" have only one pair of wings, when winged, and these are usually membranous The hind pair is represented by a pair of short, knobbed organs known as the balancers or halteres Large compound eyes are present and most species possess three simple eyes, ocelli. The mouth parts as already described in Chapter VI function as suctorial organs, but are subject to great variation; many species are provided with piercing stylets which vary widely in form. The metamorphosis is complete in that there are four stages in development, egg, larva, pupa and adult. Some species are viviparous, notably the tsetse flies. A knowledge of the larvae of Diptera is highly important, particularly the muscoid maggots which frequently cause myiasis, and aquatic larvae in relation to mosquito and gnat control.[1]

The Diptera have a wide range in breeding and feeding habits. There are very few habitats suitable for animal life which have not been invaded by the flies. There is a species of fly known as the petroleum fly, *Psilopa petrolei* Coq , which develops in crude oil. Many species are known to be of great importance as agricultural pests, and many are beneficial in that they are predators on other insects or serve as scavengers.

Classification of the Diptera.—In the classification of Diptera, wing venation is commonly used (Fig 58). The great diversity of antennal characters provides a useful series of characters, as do the arrangements of spines (chaetotaxy) on the body of certain species.[2]

The Diptera are usually separated into two suborders (1) Orthorrhapha, referring to the species in which the winged insect escapes from the puparium (more correctly the last larval skin) through a T-shaped antero-dorsal split, as in horseflies, buffalo gnats and mosquitoes; and (2) Cyclorrhapha, in which the insect escapes from the puparium through a circular opening, in fact it pushes off the anterior cap by

* The student is referred to "The Families and Genera of North American Diptera," by C. H. Curran, 1934. The Ballou Press, New York, 512 pp

means of pressure exerted by the bladder-like ptilinum located on the head of the insect, as in houseflies and blowflies.

For the purposes of this book the Diptera are divided into three suborders. (1) Nematocera, in which the antennae are filiform and many-jointed, as in mosquitoes; (2) Brachycera, in which the antennae are short, not filamentous, generally three-segmented, variously formed, as in horseflies; (3) Cyclorrhapha as described above, antennae, brachycerous, generally three-segmented and frequently bearing an arista on

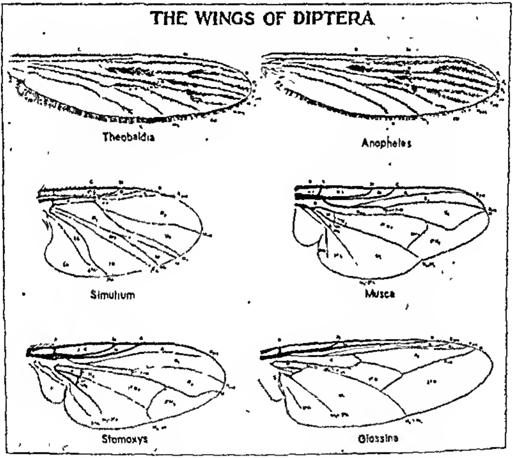


FIG. 58 —Wings of Diptera For explanation of venation see Figure 13

the terminal joint, ptilinum usually present as in houseflies and blowflies.

SUBORDER I. NEMATOCERA

Larvae with well developed, exserted head and horizontally biting mandibles; pupa free. Antennae of imago many-jointed, longer than the head and thorax, the majority of the joints usually alike; arista wanting. Palpi usually four- or five-jointed, pendulous. Discal cell generally absent, cubital cell when present widely open.

Suborder II. Brachycera

Larvae with incomplete head, usually retractile, and with vertically biting mandibles; pupa free. Antennae of adult shorter than thorax, very variable, generally three-segmented with last elongate; arista or style when present terminal. Palpi porrect, one- or two-segmented. Discal cell almost always present, cubital cell contracted before wing margin or closed.

Suborder III. Cyclorrhapha

Larvae with vestigial head; pupa coarctate; antennae of adult three-segmented with arista usually dorsal in position. Palpi one-segmented. Discal cell almost always present. Cubital cell contracted or closed. Head with frontal lunule and usually with ptilinum

Some Families of the Order Diptera *

Suborder Nematocera

A. Mesonotum with an entire V-shaped suture......(Crane Flies) Tipulidae
AA Mesonotal suture transverse, not V-shaped
  B. Costa continued around the margin of the wings, though weaker behind the apex
    C. Wings short and broad, folded roof-like over the body when at rest, usually pointed
      (Moth Flies, Sand Flies, Owl Midges) Psychodidae
    CC. Wings long, or if broad, the apex very broadly rounded, always lying flat over the back when at rest
      D. Apical veins strongly arched.......(Dixa Midges) Dixidae
      DD Veins straight or nearly so
        E Proboscis not elongate, extending but little beyond the clypeus; wings with scales (when present) confined mostly to the fringe.. ....Chaoboridae
        EE Proboscis elongate, extending far beyond the clypeus; wings with the veins and margins with scales
          (Mosquitoes) Culicidae
  BB Costa ending at or near the apex of the wing
    C Wings very broad, the posterior veins weak and poorly developed . ...(Black Flies, Buffalo Gnats) Simuliidae
    CC Wings narrow and long, the posterior veins stronger.
      D Wings lying flat over the back when at rest, metanotum short and without a longitudinal groove; femora sometimes swollen . ...(Biting Midges) Ceratopogonidae
      DD Wings lying roof-like over the back when at rest, metanotum long and with a median longitudinal groove, legs long and slender . . . .(Midges) Chironomidae

Suborder Brachycera

A. Third antennal joint annulated; arista absent
  (Horseflies, Deerflies) Tabanidae

* Classification adapted from Curran (loc cit).

AA. Third antennal joint not annulated, but if annulated with extremely long flagellum with terminal arista; squamae vestigial; normally shaped flies .... (Snipe Flies) Rhagionidae (Leptidae)

Suborder Cyclorrhapha

A. Anal cell closed very close to the wing margin; a spurious vein running obliquely between the third and fourth longitudinal veins (Flower Flies) Syrphidae

AA. Anal cell usually shorter; no spurious vein.

B. Second antennal segment with a longitudinal seam along the upper outer edge extending almost the whole length; posterior calli definitely formed by a depression extending from behind the base of the wings to above the base of the scutellum (Calypteratae: Muscoidea)

C. Metascutellum developed, appearing as a strong convexity below the scutellum; hypopleura (meron of Snodgrass) with strong bristles .... (Tachina Flies) Tachinidae

CC. Metascutellum weak or absent, or if developed there is only hair on the hypopleura

D. Oral opening and mouth parts very small; hypopleura with abundant long hair.

E. Scutellum extending far beyond the base of the metanotum; metascutellum never developed (Robust Botflies) Cuterebridae (Oestridae)

EE Scutellum very short; metascutellum usually strongly developed; palpi usually large. . (Botflies) Oestridae

DD. Oral opening normal; hypopleura with a row of bristles or only short sparse hair.

E. Hypopleura with a row of bristles.

F. Apical cell strongly narrowed apically (Flesh Flies) Metopiidae*

FF. Apical cell not at all narrowed apically Muscidae†

EE Hypopleura with fine, short hai r or bare....Muscidae

BB. Second antennal segment rarely with a wel f developed dorsal seam, the posterior calli not differentiated (except in *Gasterophilus*): squamae small (Acalyptratae)

C. Mouth parts vestigial, sun ry small oral pit (Horse B asterophilidae (Oestridae)

CC. Mouth parts well develope l opening large. Ocellar triangle large; fifth vein w uct curvature near the middle of the discal cell. . (F s) Chloropidae (Oscinidae)

* Includes the Sarcophagidae, part of the T lae and Muscidae of Williston's Manual.

† Includes the Scatophagidae (Cordyluridae), myida e and those Muscidae (of the Williston Manual) lacking hypopleural b

Family Simuliidae

(Buffalo Gnats—Black Flies)

Characteristics.—The family Simuliidae includes the insects commonly known as buffalo gnats, black flies, and turkey gnats. They are small (1 to 5 mm. long) blood-sucking flies, with bladelike piercing mouth parts in the female, but more or less rudimentary in the male. The thorax presents a strong development of the scutum and reduction of prescutum resulting in a prominent hump. The antennae are ten- to eleven-jointed, the eyes of the female are distinctly separated (close together

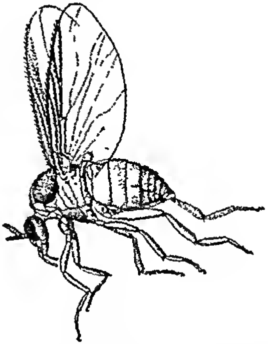


Fig. 59.—A buffalo gnat, *Eusimulium pecuarum*. (Redrawn after Garman)

and prominent in the male, i.e., holoptic), ocelli absent, palpi four-jointed, wings broad and iridescent, with distinct alulae, the venation being characterized by a strong development of the costal veins (Fig. 59).

Life history.—Buffalo gnats often occur in enormous swarms in certain localities during late spring and early summer, causing great annoyance to livestock and human beings. They are particularly abundant in the north temperate zone and subarctic zones.

Although running water is favored as a breeding place, such as shallow mountain creeks, the gnats may also breed in roadside ditches of more slowly moving water. The gnats may be found in abundance a

mile or two from water, probably in search of food. The eggs to the number of 350 to 450 per female are deposited in masses at the water surface of aquatic plants, logs, and water-splashed rocks. Comstock says he has often watched the gnats hovering over the brink of a fall where there was a thin sheet of swiftly flowing water, and has seen them dart into the water, and out again. At such times he has always found the surface of the rock more or less thickly coated witb eggs, and has no doubt that an egg is fastened to the rock each time a fly darts into the water. The shiny eggs are at first creamy white, changing to almost black.

The time required for hatching is from 5 to 30 days, depending on temperature and motion of water. In running water at a temperature of 20° to 22° C. the incubation period is four to five days.[3] The newly emerged larvae attach themselves to submerged objects, such as stones, logs, etc., by means of silken threads. Movement from place to place is gained by shifting their anchorage. In some favorable location, such as the riffles on the downstream side of an old log partially damming a little stream, there may be thousands of these tiny spindle-shaped larvae. The larvae as well as the pupae being provided witb gill filaments usually remain submerged. The larval period of some species is said to require but three to five weeks. The food of the larvae consists of small crustacea, protozoa and algae. The larval period for *Simulium ornatum* Meigeo is given by Smart[4] at 7 to 10 weeks when temperatures io the stream ranged between 9° to 15.5° C.

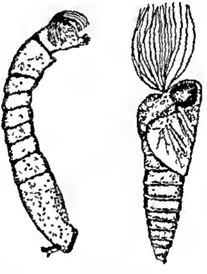
The pupal period is quite short in some species, requiring not over five or six days, while others evidently require nearly a month. It is also true that temperature influences this stage, i.e., cooler weather retards the emergence of adults. Smart gives the pupal period for *S. ornatum* Meig. as 3.75 days at a coostant temperature of 21° C. In some species there is contioual breeding from early spring to late autumn with overlapping generations; in others there is evidently one sudden brood coming fairly early in the spring with stragglers following. They overwinter in either the larval or egg stage.

Larvae.—The brown to whitish larvae are cylindrical, twelve-segmented, slightly thinner in the mid-region, and when fully grown are from 10 to 15 mm. in length (Fig. 60a). The posterior end of the body is provided with a toothed disk-like sucker, composed of two modified parapodia. The anterior proleg is also modified into a prehensile toothed disk. By means of these organs the larvae move from place to place with a looping motion. The larvae are attached to rocks or other supports io tbe water by means of the posterior sucker, the hooks of which tbey insert into the network of silken threads produced by secretioos from the salivary glaods with which they have covered the substratum. The

larvae may hang from threads produced in similar fashion or travel along their length.

Although the larvae are provided with a well-developed tracheal system, and nine pairs of spiracles may be observed, these are not *open*, and respiration is carried on by means of gills recognized as branched retractile structures located dorsally on the last abdominal segment. The fan-shaped filamentous structures located on the head are for the purpose of creating a current by means of which food is drawn to the mouth.

Pupae.—When the larvae are ready to pupate, each spins a crude pocket-like cocoon open at the upper end. The pupae are provided with respiratory filaments attached anteriorly to the dorsal portion of the thorax. The filaments are often quite numerous and because of their constancy in number in a given species are of diagnostic value (Fig. 60b).



a b

Fig. 60.—(*a*) Larva and (*b*) pupa of *Simulium*; latter removed from cone shaped cocoon (Redrawn after Lugger from Washburn)

Classification.—The family Simuliidae is divided into four genera according to Dyar and Shannon,[6] viz.:—the three genera *with the radius setose* on its entire length: (1) *Parasimulium* with the radius joining the costa at the middle of the costal vein, radial sector forked, antennae ten-jointed; (2) *Prosimulium* with radius joining the costal vein far beyond its middle, radial sector with a long fork, second hind tarsus without dorsal incision, front usually broad; (3) *Eusimulium*, radius also joining the costal vein far beyond its middle, but radial sector simple, and hind basitarsus produced or not produced apically, and second hind tarsus with or without dorsal incision and less than twice the width of the basitarsus, front narrowed; (4) *Simulium*, radius bare between the stem vein and base of the radial sector, radial sector simple, hind basitarsus produced apically, the second hind tarsus with dorsal incision and less than twice the width of the basitarsus.

The bite.—There is perhaps no other insect of equal size that can inflict so painful a bite as can the buffalo gnat. The mouth parts are of the dipteron type (similar to horsefly), consisting of six bladelike lancets.

Human beings as well as domesticated animals are viciously attacked. The eyes, ears, nostrils, wrists and all exposed parts of the body are subject to attack. The extreme pain and the resultant local swelling, and

occasional complications, indicate the presence of an active venom. Losses due to the bite of this fly are estimated variously by stockmen. Myriads of these gnats appear after the spring floods of the Mississippi River and its tributaries. Horses, mules and cattle are often killed in a few hours by the venomous bites and loss of blood. This sudden appearance of the gnats is explained by the large accumulation of eggs that have been washed into this area during floods. These eggs do not hatch until the next flood causes movement of the water which when flowing and well aërated causes the larvae to hatch and develop rapidly.

Relation to disease.—Owing to the intermittent bloodsucking habits of the buffalo gnats, it has long been suspected that they might play a rôle in the transmission of disease.

Since the rather startling report of Dr. Louis W. Sambon [6] in 1910, ascribing the transmission of pellagra to a buffalo gnat, the study of the Simuliidae with regard to disease transmission has taken on new impetus. The gnats, however, have evidently no relation to this disease. Pellagra has been carefully studied by the United States Public Health Service, and in the Public Health Reports of October 23, 1914, Goldberger states that pellagra is neither infectious nor contagious, that it is essentially of dietary origin, dependent on some yet undetermined fault in diet, and that the disease does not develop in those who consume a mixed, well-balanced and varied diet.

Onchocerciasis.—Onchocerciasis, a disease of natives of certain portions of Africa, Mexico and Central America, is caused by filarial worms, *Onchocerca volvulus* (Leuckart), measuring from 35 to 50 cm. in length in the female, less in the male, which require black gnats as intermediate hosts. These worms occur in conspicuous nodular tumors located primarily on the trunk, shoulders and head. Several adult worms and numerous larvae (produced viviparously) usually occur in each tumor. Serious involvements of the eye often resulting in complete blindness occur in many cases evidently due to migration of the larvae. Strong [7] points out that from a clinical standpoint the association of ocular disturbances with the disease is emphasized by the high percentage of failing vision and blindness in a locality where at least 95 per cent of the populations are infected with the parasite and have demonstrable nodules. The student should particularly consult a treatise on ocular onchocerciasis by Hisette.[8]

Blacklock,[9] working in Sierra Leone, has shown that when the larvae are taken up with the bite of *Simulium* flies, they migrate from the fly's stomach, finding lodgment in the thoracic muscles where further development takes place and then travel to the head and finally the labial structures of the fly, where escape is made when the fly bites and infection of the human being is accomplished. The species of fly observed in these

experiments was *Simulium damnosum* Theob., a widely distributed black gnat of tropical Africa. Bequaert[10] points out that of 57 species of Simuliidae described from the Ethiopian region, five only are definitely reported as biting people, but all must be looked upon with suspicion as possible carriers of onchocerciasis, although *S. damnosum* Theob. and *S. neavei* Roubaud are the only ones positively incriminated.

Strong[11] investigated the disease in Guatemala, where he reports it is characterized by the formation of nodular tumors situated on or in the region of the head. He reports three species of black gnats as vectors, namely *Eusimulium ovidum* Hoffman, *Eusimulium ochraceum* Walker and (probably) *Eusimulium mooseri* Dampf The last two species are reported as being vectors in the states of Oaxaca and Chiapas, Mexico, by Dampf.[12]

Bovine onchocerciasis.—It has been pointed out by Steward[13] that bovine onchocerciasis is of considerable economic importance in Australia, that the "worm nodules" due to *Onchocerca gibsoni* Cleland and Johnston cause losses to the state of Queensland estimated at £500,000 per annum. The work done by Steward in England with *Onchocerca gutturosa* Neumann proved that this latter parasite is transmitted by *Simulium ornatum* Meigen. He showed that the filariae are conveyed from the skin of the cow by the bite of the fly to the mid-gut of the insect, where development commences. About 10 days after ingestion they have reached the "sausage" stage in the thoracic muscles, and by the nineteenth to twenty-second day they migrate forward to the head ready for emergence from the proboscis when the gnat feeds again.

Leucocytozoön infections of poultry.—The name Leucocytozoön was given to certain Sporozoa found in the blood of birds by Danilewsky in 1890, and in 1895 Theobald Smith discovered a *Leucocytozoon* in the blood of turkeys; this parasite was named *Leucocytozoön smithi* by Volkmar. In 1932 Skidmore,[14] working in Nebraska, reported the successful transmission of this parasite by *Simulium occidentale* Town. In 1938, Johnson et al.[15] reported transmission through the agency of *Simulium nigroparvum* (Twinn). Johnson and his associates state that when taken into the stomach of the fly gametes are formed, macrogametes being clearly observable as well as the zygote

An important infection of both domestic and wild ducks caused by the protozoön parasite, *Leucocytozoön anatis* Wickware (1915), occurs in Michigan according to O'Roke[16] who proved that the disease is transmitted by the black fly, *Simulium venustum* Say. The development of the organism within the body of the gnat is cyclico-propagative, resembling closely the life cycle of the plasmodium of malaria in the anopheline mosquito. O'Roke states that the asexual cycle in the duck

requires ten days and the sexual cycle in the gnat not more than five days, with field evidence that it may be as short as two days or less.

Common species.—Only one species is given under the genus *Parosimulium* by Dyar and Shannon, namely *P. furcatum* Malloch from Humboldt County, California. *Prosimulium fulvum* Coq. is a widely distributed species in the mountainous regions of the west and along the Pacific coast from Alaska to California; *P. hirtipes* (Fries) is said to be confined to the region east of the Mississippi and north of the Carolinas. It rarely attacks man, according to Dyar and Shannon, though it is known on occasion to bite rather severely; it is not considered an important pest of livestock.

Eusimulium pecuarum (Riley) is known as the southern buffalo gnat and is a great scourge of livestock as well as of man in the Mississippi Valley. During the height of the gnat season in the early spring, work on plantations is often greatly handicapped because of the annoyance to work animals. *E. minus* D. and S. is a widely distributed western and Pacific coast species with the type locality indicated as Yosemite. It resembles the buffalo gnat but is smaller and darker.

Simulium pictipes Hagen occurs in the eastern United States. It is said to be an inoffensive species. *Simulium vittatum* Zetterstedt is widespread throughout North America and is a common species in Europe. It attacks man and livestock freely. *Simulium occidentale* Townsend (*Simulium meridionale* Malloch), known as the turkey gnat, is also a common and widespread species throughout North America, but particularly in the southern states where it appears in late spring following the buffalo gnat. It attacks poultry, biting the combs and wattles, and is said to cause symptoms similar to "cholera," hence the name "cholera gnat." *Simulium venustum* Say is the black fly. It is one of the most annoying and widespread species. It torments fishermen and campers in New England and Canada. The gnats occur in the greatest numbers during June and July. *Simulium columbaczense* (Schiner) is the famous Columbacz gnat of middle and southern Europe. Patton and Evans [11] (page 193), citing Ciurea and Dinulescu, report that in 1923 two immense swarms of this fly invaded southwest Roumania in May, June and July, causing the death of 16,474 domestic animals, including cattle, horses, pigs, sheep and goats. Large numbers of deer, foxes and hares as well as other wild animals were killed at the same time, according to these authors.

Black-gnat control.—Knowing the breeding habits of black gnats, it will be appreciated that control is a difficult task. There is indeed no practical method of control. The writer has repeatedly recommended that streams in which these insects are breeding should be kept as free from debris as possible, including submerged roots and dipping branches of

overbanging trees. It is possible to do this in the immediate vicinity of communities, but prevailing winds may nevertheless bring swarms of gnats from a distance. The removal of debris from streams lessens the opportunity for them to deposit their eggs. Old logs lying crosswise of a stream are a particular menace because shallow waterfalls are thus usually produced, and afford ideal breeding places for the gnats. The fact that the larvae tend to congregate in masses in the swifter parts of streams in which they are breeding makes it possible to remove them in quantities when once located.

Domesticated animals may be well greased with ointments containing fish oil. The U. S. Department of Agriculture recommends an emulsion made of one pound of fish oil soap, three quarts of fresh cylinder oil, one gallon of water, and one gallon of kerosene-extract of pyrethrum. The water and soap are heated to near boiling and then stirred vigorously while the mixture of kerosene extract and cylinder oil is slowly poured in. While many repellents are on the market, few are of any benefit and practically none affords absolute relief. Smudges act as good repellents, also oil of citronella applied to the hands and face. The following formula is recommended: castor oil 1 oz., pennyroyal ½ oz., citronella ¼ oz., camphor ¼ oz., pine tar ½ oz.

Family Psychodidae

(*Moth Flies—Sand Flies*)

Family Psychodidae.—The family includes tiny goats known as owl midges, moth flies, or sand flies The ovate, usually pointed wings, and body are densely covered with hairs, whence the name moth flies; in the *Psychoda* flies, the wings when at rest lie roof-like over the abdomen. Because of the faint transverse venation the wings appear to have only longitudinal veins. The antennae are usually fairly long and from twelve- to sixteen-segmented.

The family may be divided into two subfamilies, (1) Psychodinae, non-bloodsucking, in which the wings are held roof-like over the body; and (2) Phlebotominae, females bloodsucking, in which the wings are held at an angle of about 45 degrees.

Psychoda flies.—Several species of *Psychoda* are commonly found in great numbers about sewage disposal plants, cesspools, and occasionally about wash basins in bathrooms where the larvae may develop in sink drains in spite of hot water and soap. A common Pacific coast species is *Psychoda pacifica* Kincaid, brown in color, measuring from 2 to 2 3 mm. in length. Although the flies of this genus are non-bloodsucking, they may breed in such numbers in the filter beds of sewage disposal plants, as the author has personally observed, as to constitute a real

annoyance to neighboring households. The life history of these flies is quite short, averaging about two weeks.

Phlebotomus flies.—The genus *Phlebotomus*, commonly known as sand flies (Fig. 61), includes a number of species of small size measuring from 3 to 5 mm in length; the females are bloodsucking.

The habits of the *Phlebotomus* flies are described by several authors, among them Townsend,[18] who says that the tiny bloodsucking gnats

"avoid wind and sun and full daylight They appear only after sunset, and only then in the absence of wind. They enter dwellings if not too brightly lighted, but are not natural frequenters of human habitations. They breed in caves, rock

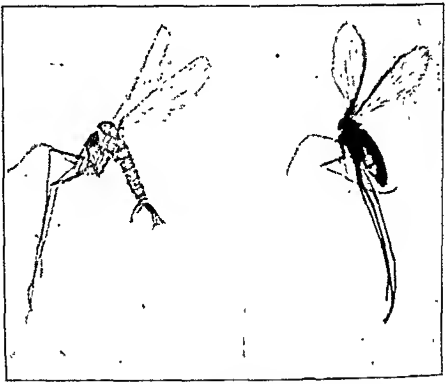


FIG 61 — Phlebotomus or sand fly (male, left; female, right) × 8

interstices, stone embankments, walls, even in excavated rock and earth materials. . . . They hide by day in similar places or in shelter of rank vegetation Deep canyons, free from wind and dimly lighted, are especially adapted to them Thick vegetation protects them from what wind there is by day or night. . . . The flies suck the blood of almost any warm-blooded animal, and even that of lizards in at least one known case Thus they are quite independent of man, and this accords with the verruga reservoir being located in the native fauna."

The eggs are deposited in dark, moist though not wet crevices in caves, embankments, walls, etc., in batches of about 50. The incubation period is said to be from 9 to 12 days (Whittingham and Rook).[19] The larvae have long anal spines, the mouth parts are mandibulate; they feed

on organic debris, mainly excrementous matter, and after four molts form a naked pupa. The entire life history requires from six to eight weeks, and even a month in warmer climates.

Verruga peruviana, also known as Carrion's disease or Oroya fever, is a disease confined to South America (Peru, Ecuador, Bolivia and Chile) and is found on the western slopes of the Andes in certain narrow canyons at an altitude of from 3,000 to 10,000 feet. The disease in its initial symptoms is characterized "by a fever lasting from fifteen to thirty days, profound anemia, prostration and a high mortality. If the patient does not die in this stage, the fever begins to abate and the eruptive or verruga stage commences." The causative organism is the so-called X-body or Bartonia body, *Bartonella bacilliformis* Strong

Townsend [20] reported having infected a hairless dog, *Canis caraibicus* (Lesson), by injecting subcutaneously in the right shoulder of the animal a serum containing the triturated bodies of 20 female *Phlebotomus verrucarum* Townsend collected at random in a verruga canyon. The incubation period was said to have been six days when the typical eruption began to appear. The same author [21] reports a human case which he believes to have resulted from the bites of *Phlebotomus* flies. Although the Verruga Expedition Report [22] does not consider Townsend's evidence as conclusive, the latter again presents his arguments in favor of the *Phlebotomus* fly theory in a paper published in the American Journal of Tropical Diseases and Preventive Medicine, July, 1915 (pp. 16–32). Townsend's work has since been substantially confirmed by Noguchi, Shannon, et al. (1929),[23] who added another vector, namely *Phlebotomus noguchii* Shannon.

Pappataci fever.—Pappataci fever, also known as three-day fever, sand-fly and phlebotomus fever, is a dengue-like disease of sudden onset, the attacks of fever lasting two or three days. It occurs mainly on the islands and coastal areas of the Mediterranean, parts of Austria, Hungary, South China, Ceylon and India. The causative agent is unknown.

After inoculation by a *Phlebotomus* fly there is an incubation period of about seven days giving rise to the active symptoms, and a brief period of probably not over 24 hours during which the patient's blood is infectious. It is only during this brief period that the flies can become infected, and the incubation period in the insect is apparently from 7 to 10 days. The vector is *Phlebotomus papatasii* Scopoli, and probably other species.

Kala azar.—Kala azar or dumdum fever is a leishmaniasis traceable to *Leishmania donovani* (Laveran and Mesnil). It occurs endemically in the Mediterranean coastal area, in Iraq, North China, India, southern Russia and other parts of the world. It results in enormously enlarged spleens and other serious envolvements (see Craig and

Faust, Clinical Parasitology, 1937). It is regarded as a frequently fatal disease resulting in death within a few weeks in acute infections and in from two to three years in chronic cases. Various species of bloodsucking arthropods have been suspected from time to time as being vectors, among these the Indian bedbug, *Cimex hemipterus* (Fabr.), with which Patton (1907) worked with some degree of success (see Chapter VIII). The low susceptibility of laboratory animals made progress difficult, but with the discovery that hamsters were highly susceptible to the infection more rapid progress was made in the laboratory phase of the investigation. Patton and Hindle [24] (1927), as well as Young and Hertig [25] and Napier, Knowles and Smith before them (1925), observed that the Leishmania bodies underwent development in the intestinal tract of *Phlebotomus* flies after being ingested. Flagellation is said to take place in the mid-intestine. The cycle in the gnat is completed in from four to five days. Evidence of infection by the insect is very meagre though Shortt and Smith, et al.,[26] 1931, report successful transmission by the bite of *Phlebotomus argentipes* Annandale and Brunetti, believed to be the Indian vector. Other species, notably *Phlebotomus chinensis* Patton and Hindle in China, and *P. sergenti* Parrot in northern Africa, are believed to be vectors.

Transmission by the bite of the fly is doubted by Southwell and Kirshner.[27] These investigators point out that the bite of the sand fly causes an irritation and the person bitten scratches the bite, thus crushing and killing the infected insect. The leptomonads, the infective forms, do not invade the mouth parts in either *P. argentipes* A. and B. or *P. chinensis* P. and H. Thus infection by the bite is believed to be unlikely, though infection as the result of crushing infected flies on the skin appears to be possible.

Oriental sore.—Oriental sore is a cutaneous leishmaniasis caused by *Leishmania tropica* (Wright); it has a wide distribution in Mediterranean areas, Palestine, Arabia, Asia Minor, Iraq, India, French Congo and other parts of the world. It is not necessarily coextensive with kala azar. In oriental sore the leishmanias inhabit the skin and do not invade the viscera. In a series of papers by Adler and Theodor,[28] evidence is advanced to incriminate *Phlebotomus papatasii* Scopoli. These workers found a cyclical development of the *Leishmania* in the fly requiring from 8 to 21 days. Infection of a human was accomplished by rubbing the infected mid-gut of the insect into the scarified skin, and flies were reinfected successfully from the sore thus produced. Infection by the bite did not occur.

Other species of Phlebotomus.—*Phlebotomus vexator* Coq. has been described from the United States; *P. queenslandi* Hill, *P. brevifilis* Tonnoir, and *P. englishi* Tonnoir are listed from Australia.

Control.—Marett [29] suggests the following prophylactic measures, viz.: Facing of walls, the removal of heaps of stones and the blocking of all holes which might serve as shelter places for the flies; also covering the ventilators with fine-meshed wire gauze, and the cleaning of all rough ground from weeds, so that all holes may be discovered and filled up with beaten earth. The encouragement of gardening on such grounds is, he thinks, also desirable. Large embankments should be planted with native aromatic plants such as thyme, pennyroyal, etc., and kept well earthed.

Family Ceratopogonidae

(*Biting Midges—Punkies*)

Characteristics.—The Ceratopogonidae are very small, slender, bloodsucking gnats (males do not bite) resembling the non-biting midges belonging to the family Chironomidae, to which family they are commonly ascribed. In their biting habits they resemble the black flies (Simuliidae) and are frequently mistaken for them. Among the twenty or more genera comprising the family, three will serve the purpose of this section, namely *Culicoides* (Fig. 62); *Ceratopogon*, and *Leptoconops*, commonly known as "punkies," "no-see-ums" or "sand flies." They measure from 1 to 3 mm. in length. The larvae are aquatic or semiaquatic. A key to the North American *Culicoides* numbering thirty species is given by Root and Hoffman.[30]

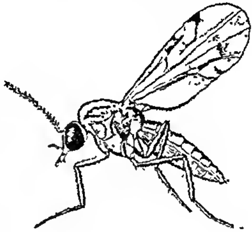


Fig. 62.—Female *Culicoides* sp., a vector of *Onchocerca volvulus* in Mexico. (After Dampf.)

Culicoides canithorax Hoffm., *C. melleus* Coq., and *C. dovei* Hall constitute a serious economic problem in the summer resort areas of the Atlantic coast, particularly about fresh-water inlets and tide-water pools where these midges are most numerous. Dove, Hall and Hull [31] report that the larvae are found in decaying humus of the densely shaded areas at the edges of the grass marshes of the upper Atlantic coast. The period required for development appears to last from 6 to 12 months according to these authors.

The larvae and pupae of *Culicoides guttipennis* Coq. have been taken from treeholes of the live oak in Mississippi (Hinman).[32]

Ceratopogon stellifer Coq. is reported to be a severe biter in Arizona and New Mexico.

Leptoconops torrens Townsend and *L. kerteszi* Kieff. constitute a serious pest in the territory adjacent to the rivers in the lower Sacramento and northern San Joaquin valleys in California. Freeborn and Zimmerman [33] describe this as follows:

"Certain areas locally known as 'black alkali' locations seemed to form the foci from which these pests were blown by winds over wide areas, constituting such a pest in some seasons that agricultural field work was brought to a standstill and even town dwellers were driven indoors until nightfall. The bites are extremely irritating, causing nodular, inflamed swellings that itch persistently for several days or even weeks. In some individuals, particularly those inclined to be stout, the swellings caused by the bite become vesicular, rupture, and produce a moist open lesion that 'weeps' a serous exudate for weeks, finally healing with a definite red scar. The insects insinuate themselves beneath the clothing and apparently prefer to bite at some point where their progress is impeded, such as around the hat band, at the belt line, or where the sleeves are closely rolled against the arms, and at the shoe tops. The usual repellents that are effective against mosquitoes are of little use against these insects, the only casualties noted being the ones that were actually trapped or drowned in the oily applications used"

Culicoides austeni Carter, Ingram and Macfie has been reported by Sharp [34] as an intermediary host of *Acanthocheilonema perstans* (Manson) [*Dipetalonema perstans* (Manson)]. The embryos of this worm are found in the peripheral circulation both by day and by night. Sharp has observed that diurnal periodicity is the more common. In the vast majority of cases it is said to be non-pathogenic. It is primarily equatorial and African in distribution, though it occurs also in British Guiana and in New Guinea Sharp has shown that the microfilariae undergo metamorphosis in the body of *Culicoides austeni* Carter, Ingram and Macfie, increasing to three times their original length before they appear in the proboscis of the insect. The cycle in the fly requires seven to nine days. Sharp states that it is probable that *Culicoides grahami* Austen will also prove to be a natural carrier. Buckley [35] found that *Culicoides furens* Poey transmits the filarial worm, *Mansonella ozzardi* (Manson), in the Antilles, and Dampf [36] points out that this species of gnat is widely distributed along the coast of the Gulf of Mexico and the Caribbean Sea.

Control.—Because of the variety of breeding places involved, it becomes necessary first of all to determine these for the species giving trouble. Some species breed in salt marshes in which case dikes, tide gates and other salt-marsh control devices must be applied; other species breed in mud and plant debris along the margins of fresh-water streams or ponds, in which case removal of vegetation, channelization and filling

in low ground will be helpful; still other species breed in holes in shade trees, in which case holes should be treated with creosote or otherwise made unfavorable for breeding.

Sand flies may be excluded from the house, according to the United States Bureau of Entomology and Plant Quarantine, by applying a mixture of 1 part pyrethrum extract concentrate (20 to 1) and 20 parts lubricating oil (S.A.E 5), by means of a brush or rag to window screens. This mixture, it is reported, will exclude the gnats from the house for 24 to 48 hours.

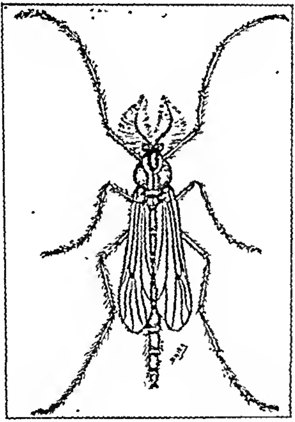


FIG 63.—A male midge (Chironomidae), commonly mistaken for a mosquito (After Osborn) × 12

FAMILY CHIRONOMIDAE

(Midges)

Family Chironomidae.—Although the midges are commonly mistaken for mosquitoes they bear little resemblance to them on closer examination. In the midges the proboscis is short and not adapted for piercing, the palpi are three- or four-jointed, the wings are bare or

haired. The antennae are plumose in the males and sparsely haired in the female (Fig. 63). Midges are widely distributed and may often be extremely abundant in the vicinity of standing water, since the larvae are aquatic. Occasionally great swarms of these insects hover in the air toward evening and produce a distinct humming sound. They are attracted to light in great numbers. The family is a very large one, comprising nearly 2,000 species.

Many of the larvae are red in color, hence the name "blood worm." The larvae are worm-like (Fig. 64) and move by creeping or looping, they have a closed (apneustic) respiratory system and need not come to the surface for air as do mosquito larvae. Most species are bottom feeders and scavengers in habit. While occurring most abundantly in shallow shore water with vegetation such as reeds and tule, they have been taken at great depths from the bottom of lakes; some species breed in swiftly flowing water.

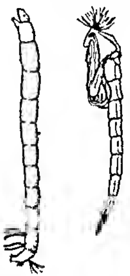


Fig. 64.—Larva (left) and pupa (right) of a chironomid gnat (midge). (Larva redrawn after Needham and pupa redrawn after Grunberg.)

Burrill[37] in a very interesting paper on the swarming of midges states that under the conditions observed they swarm an hour or two in the early morning sunlight, then mostly stop flying and rest on such objects as grass, the underside of tree leaves, tree trunks and porch screens. They may fly throughout a cloudy day. He also observed a late summer swarm of *Chironomus plumosus* Burrill fly until after midnight.

Family Dixidae

(*Dixa Midges*)

Dixa midges are usually placed in the family Culicidae (mosquitoes) and are designated as a subfamily, Dixinae; however, for the purposes of this work they are separated from the mosquitoes. They resemble mosquitoes in wing venation but are almost devoid of hairs and scales, and the proboscis while somewhat projecting is not fitted for piercing. This family is mentioned here particularly because the larvae are frequently mistaken for those of Anopheles, being commonly found in similar situations and also because the adults resemble and are related to the true mosquitoes. Dixa larvae are usually seen at the surface of water among vegetation and debris moving in a horizontal U-shaped position. The student is referred to the work of O. A. Johannsen, "North American Dixidae" in Psyche, vol. xxx (1923), pp. 52–58.

Family Chaoboridae

(Chooborid gnats)

Family Chaoboridae.—This family is usually regarded as a subfamily (Chaoborinae) of the Culicidae, mosquitoes, but for the purposes at least of this book the less commonly recognized family rank is used. They are non-bloodsucking and the gill-breathing larvae which live in deeper water are almost transparent and are seen with some difficulty, except when in motion, even in fairly clear water, hence the name "phantom larvae." The tiny lead-colored cigar-shaped eggs are deposited in

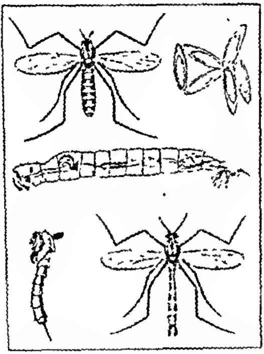


Fig. 65.—A chaoborid gnat, *Chaoboris lacustris* Top left, female gnat, top right, eggs; lower left, pupa; lower right, male gnat; middle figure, larva

great numbers on the surface of still water such as ponds, lagoons, lakes, etc. The eggs soon sink to the bottom The incubation period is less than 24 hours. The larvae grow slowly during the summer, reaching approximately full growth by winter, remaining thus through the winter, and pupating in the early spring The pupal stage requires about two weeks. The pupae quickly come to the surface where the gnats literally "pop" out of the pupal skins, balance on the water momentarily and then fly shoreward. *Chaoborus lacustris* Freeborn (Fig 65) on which the above life history is based is a distinct nuisance along the shores of Clear Lake, California.[39]

Family Chloropidae

(*Hippelates flies—Eye gnats*)

Hippelates flies.—These flies are members of the family Chloropidae (Oscinidae), commonly known as frit flies. Unlike the foregoing gnats discussed in this chapter, all Nematocera, the Chloropidae have short aristate antennae. The members of the genus *Hippelates* Sabrosky (hind tibiae with a distinct, curved, shining black, apical or subapical spur), are as a rule very small flies frequently called "eye gnats" or "eye flies" because they have a liking for lachrymal secretions, also sebaceous secretions, pus, and blood. They are extraordinarily persistent and if brushed away will quickly return to continue engorging themselves. They are non-biting; however, the labellum is provided with spines which apparently act as cutting instruments capable of producing minute multiple incisions, likely to assist pathogenic organisms carried by the insects in gaining a foothold (Graham-Smith [39]). The flies are easily mistaken for the vinegar fly, Drosophila. The larvae of most of the Chloropidae live in grass and other plants (stem maggots); however, those of the genus *Hippelates* develop in a wide variety of material such as decaying vegetable and animal matter, and excrement of various animals.

The author is aware of the need for taxonomic work and revision in this group; already Sabrosky [40] and Kumm who are giving much independent attention to the subject have made new combinations, the former referring a species of *Siphonella* (*S. circumdata* Becker) to the genus *Hippelates,* indicating the uncertainty of perhaps some of the species mentioned in the next section.

Relation to conjunctivitis.—*Siphunculina funicola* de Meyere is known as the "eye-fly" of India, Ceylon and Java and is believed to be responsible for the spreading of conjunctivitis in these countries. Roy 1928 [41] gives a chart which shows that the seasonal prevalence of this fly in Assam coincides closely with epidemic conjunctivitis.

Hippelates flies have long been looked upon with suspicion in certain parts of the southern United States in relation to a form of conjunctivitis commonly referred to as "sore eye," "pink eye," etc. A brief consideration of this matter is to be found in the Proceedings of the Entomological Society of Washington, vol. iii, pp. 178–180—a meeting held October 11, 1894, at which E. A. Schwarz presented certain notes on *Hippelates pusio* Loew in the Southern States. He stated that it was particularly abundant in Florida and annoying to man and animals, and that it is attracted to eyes and to the natural openings of the body as well as infected wounds. In this note as well as in a longer article in Insect Life for July, 1895, Schwarz throws much suspicion on Hippelates flies as vectors of "sore eye."

For a number of years, at least since 1912, there have been numerous cases of catarrhal conjunctivitis apparently of the follicular type in the Coachella Valley of California where a veritable pest of Hippelates flies flourishes in season. Nowhere else in California are there such enormous numbers of these flies and nowhere else in the state do as many cases of so-called "pink eye" exist. We have published several papers dealing with this subject. (See Herms, Journ. Econ. Ent., vol. 19, no. 5, pp. 692–695, and ibid., vol. 21, no. 5, pp. 690–693; also Herms and Burgess, ibid., vol. 23, no. 3, pp. 600–603.)

The literature dealing with "The Oscinidae as Vectors of Conjunctivitis" has been recently reviewed with great care by Graham-Smith (Parasitology, vol. 22, no. 4, pp. 457–467, 1930). This review indicates a paucity of experimental evidence but a large amount of circumstantial evidence involving Egypt, the West Indies, India, Ceylon, Java and the United States.

The fly was at the time of our Coachella investigations identified as *Hippelates flavipes* Loew. In a letter from Dr J M Aldrich dated May 19, 1927, he writes, "The species which you sent from Coachella Valley, California is *pusio* Loew. It is the same species which was identified as *flavipes* Loew by Malloch, Proc. U.S.N M , 46, 1913, p 245 His variety *pusio* on page 246 is a different form. The true *flavipes* of Loew, is the one described by Malloch on page 243, as *nitidifrons* new species, as I have ascertained by examining the types in the Museum of Comparative Zoölogy at Cambridge, Mass. The earlier literature is somewhat uncertain since the time of the original description, but probably your species is the same one that has been referred to as *flavipes* when mentioning its annoying habits." In the same letter Dr. Aldrich also writes, "In the Proceedings of the California Academy of Sciences, Vol. 4, 619, Townsend described *Oscinis collusor* from Lower California which he said was reported to cause irritation of eyes of travelers and the 'mal de ojo' of natives. I examined his types in the Academy shortly before their destruction by fire in the spring of 1906 and found that they belonged to the genus *Hippelates*, and it is quite probable that the species is *pusio*." The writer has traced the Coachella Valley species through to the Mexican border at Mexicali.

Relation to yaws.—As pointed out in the first chapter flies have been suspected as vectors of yaws (framboesia tropica) for many years and some experimental evidence has been advanced from time to time, however, the evidence collected by Kumm [12] (1935) in Jamaica with *Hippelates pallipes* Loew is most convincing. Kumm as well as others has shown that it is relatively easy to demonstrate motile *Treponema pertenue* Castellani in the "vomit drops" of eye gnats after they have fed on infectious lesions of yaws He found, however, that the spirochaetes were presumably digested in the mid-gut and hind-gut of the gnats very

soon after they were ingested, nnne being seen after an interval of two days. There was no evidenee of cyelieal development.

The gnats receive the infeetinn mnst readily by feeding on available primary lesions which exude fresh infected serum with large numbers of spirochaetes. Inneulation is effected mechanically, i.e., the unchanged spirochaetes are deposited in "vomit drops" [43] when infected gnats feed on exuding serum from wounds, exenriated areas or susceptible surfaces. The manner in which the gnats receive the infection and their general feeding habits are well described by Kumm, Turner and Peat.[44]

Life history of Hippelates pusio Loew.—This species has a wide distribution in the southern United States where the winters are mild. The adult flies are present throughout the year in the Coachella Valley (California) and are particularly annoying during two periods, i.e.,

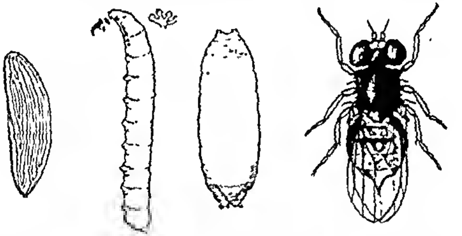


FIG. 66.—*Hippelates pusio.* Egg; larva, showing cephalo pharyngeal skeleton and anterior spiracular process; pupa; adult fly. (After Herms and Burgess except adult fly which is redrawn after D. G Hall.)

March, April, May and August, September and October. During June, July and early August the gnats are not abundant on account of extreme heat, when the daily temperatures range well above 100° F. During these months the adults are noticeable early in the morning and late in the afternoon and then in deep shade such as densely planted shrubbery, in date gardens and in the shade of the house. The fluted, distinctly curved eggs are about .5 mm. in length (Fig. 66). They are deposited on decaying organic matter of wide range. The incubation period is about three days. The larvae feed on a great variety nf decaying organic matter including excrement, provided the material is rather loose and well aërated. According to Burgess (verbal communication) the larvae will not develop naturally in closely compacted soil or putrid material, neither will they breed naturally in excrement unless it is mixed with loose earth. The larval stage under optimum conditions requires about eleven days. The

larvae may remain in this stage during the winter. Pupation takes place close to the surface of the material in which the larvae develop. The pupal stage requires about six days, giving a total of about 21 days from egg to adult fly. Except for overwintering adults, the first flies emerge from the pupae of the overwintering larvae during late February and early March when the first great wave of flies appears as noted above. Experiments performed by Hall [45] show that the larval stage averaged about 11.4 days on human excrement, on dog manure 8.7 days, on decaying oranges about 17 days. Burgess [46] points out that the majority of Hippelates gnats are bred in soil that is (1) light and friable (well drained), (2) freshly plowed (i.e., plowed not over three weeks before), and (3) contains abundant humus or vegetable matter (cover crops, manure). The control of Hippelates gnats is difficult and involves a combination of measures, such as *trapping*, using finely chopped liver as bait; *sanitation*, removal of garbage, manure piles, refuse heaps, etc., and decaying vegetable matter; also *cultural methods* such as light disking.

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CHAPTER XI

MOSQUITOES

Order Diptera—Family Culicidae

Classification and Biology

Importance.—Few insects if any can compare with the mosquitoes as pests of man and his domesticated animals. They are world-wide in distribution and great swarms may be produced in very small quantities of water, fresh and salt, foul and potable, in tin cans and reservoirs, tree holes and great marshes. Man's progress has often been challenged by mosquitoes and parts of the world still remain uninhabited by man because of these voracious bloodsuckers. Great areas of seacoast were barred by salt marsh mosquitoes until extensive abatement campaigns transformed these areas into enjoyable summer resorts and productive industrial and agricultural sections. Real estate values suffer where the mosquito pest prevails and losses due to lowered industrial efficiency are frequently considerable. Economic losses alone of this nature would no doubt justify the enormous sums now spent in mosquito abatement, and yet these losses are but slight compared with the prodigious damage done by mosquitoes to the public health, as vectors of diseases of such importance as malaria, yellow fever and dengue fever.

Family Culicidae.—The Culicidae, aquatic in their immature stages, are distinguished from all other nematoceran Diptera by (1) their characteristic wing venation (Fig. 58) as outlined by Edwards[1] as follows, subcosta (Sc) long and reaching the costa, radius four-branched, R_{2+3} forked, R_{4+5} simple, no cross-vein connection of R_1 and R_2, media (M) two-branched, cross-veins r-m and m-cu both present, Ax absent or very faint; cubitus (Cu) forked, An long and reaching wing-margin; (2) characteristic scales clothing the wings and more or less abundant on the head and body; (3) characteristics of the thorax such as the absence of a definite suture between the prescutum and scutum, completely divided pronotum.

Edwards divides the family into three subfamilies, (1) Dixinae, in which the mouth parts are short and not formed for biting, discussed in the previous chapter as Dixidae; (2) Chaoborinae, mouth parts short, not formed for biting, maxillary palpi always much longer than labium, wing scales confined to wing fringe; discussed in the previous chapter as

Chaoboridae; (3) Culicinae, the true mosquitoes, mouth parts elongate, formed for piercing, and bloodsucking in the females, though not all mosquitoes are bloodsuckers, and the males are non-bloodsucking; scales on wing veins and fringing the margin, also on the legs and body; fifteen-segmented antennae with whorls of hairs which in the males of most genera present a plumose appearance. The males of *Opifex* and *Deinocerites* do not have plumose antennae.

The larvae of the Culicidae according to Edwards are distinguished from all other dipterous larvae by the possession of a complete head capsule and the presence of only one pair of functional spiracles, situated dorsally on the eighth abdominal segment. The larvae of the Culicidae are without exception aquatic, although Edwards points out that a few species have the power of crawling over short distances out of water.

For the purposes of this work each of the three subfamilies of the Culicidae is considered as a family and as here used the family Culicidae includes only the true mosquitoes.

Classification of mosquitoes.—There are over 1,400 (Edwards, Genera Insectorum) described species of mosquitoes in the world, of which about 80 occur in North America.[2] These species may be divided into four tribes for practical purposes, (1) Megarhinini, basal half of proboscis rigid and distal portion flexible, the adults are strictly flower-feeding, and the larvae are predaceous, e.g., *Megarhinus inornatus* Walker; (2) Culicini, in which the palpi of the female are less than half as long as the proboscis, scutellum trilobed, pulvilli present, eggs laid in rafts, e.g., *Culex pipiens* Linn.; (3) Aedini, in which the palpi and trilobed scutellum are as in the Culicini but the abdomen of the female is pointed, post-spiracular bristles are present, pulvilli absent or hair-like, eggs laid singly, e.g., *Aedes vexans* (Meigen); (4) Anophelini, in which the palpi of both sexes are as long as or nearly as long as the proboscis, scutellum rounded, without lobes, eggs laid singly, e.g., *Anopheles maculipennis* Meigen.

Among the more technical characters used in classification are chaetotaxy, toothed condition of the claws (ungues), structure of pharyngeal armature, presence or absence of pulvilli, size, form and distribution of the scales, color pattern, and particularly the terminal abdominal segments of the males, genital and anal, collectively known as the terminalia. The female terminalia occasionally present characters useful in classification. Recently emphasis is being placed on larval characters and those of the eggs.

Classification based on terminalia.—The difficulties encountered in undertaking a classification of mosquitoes based on the male genitalia or more accurately the male terminalia (hypopygium of Edwards 1920,

Christophers and Barraud 1923) are (1) the necessity of macerating the specimen and mounting for microscopic study (if possible, the terminalia should be observed in alcohol in order to obtain the true relationship of the parts, rather than the single-plane view of a slide mount), and (2) the confusion of names applied to the various parts by different writers which makes it difficult to apply the published keys. The revised terminology of Freeborn (1924) [3] will be adhered to in the classification of male mosquitoes. (Fig. 67.)

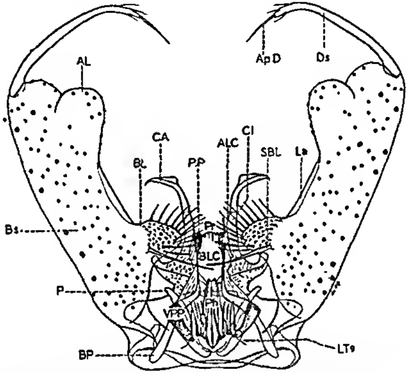


Fig. 67.—Male terminalia (hypopygium) of *Aedes squamiger*. AL, Apical lobe; ALC, Apical lobe of claspette; Ap D, Appendage of dististyle; Bs, Basistyle; BL, Basal lobe; BLC, Basal lobe of claspette; BP, Basal plate; Cl, Claspette; CA, Claspette appendage; Ds, Dististyle; La, Lacuna; LT9, Lobe of 9th tergite; P, Paramere; Ph, Phallosome; PP, Paraproct; Pr, Proctiger; SBL, Spine of basal lobe; VPP, Ventral arm of paraproct

Those segments distad of the seventh are considered as comprising the male terminalia complex. Christophers (1915) [4] first showed that following the emergence of the male mosquito, a torsion of 180° takes place at the juncture of the seventh and eighth segments; as a result the eighth tergite and those distad of it become ventral and the sternites dorsal. The terms ventral and dorsal will hereafter be used in the sense of "primitively ventral and dorsal," i.e., *before* rotation took place. The following explanation of the terminology is supplemented by Table II in which several of the major systems are compared.

1. The eighth segment is of interest in certain genera (*Theobaldia*,

Taeniorhynchus, Megarhinus), in which the tergites of some species bear rows of hairs or spines on the apical edge.

2. The ninth segment is to be considered the genital segment; the sternite, a narrow piece of chitin, and the tergite, a wider piece which may bear two spined lobes (without spines in *Anopheles*), form a ring through the membranous floor of which the genital and anal appendages project. The clasping organs (*gonostyles*, in reality the exopodites of a primitive limb) are composed of a basal piece (*basistyle*) and distal piece (*dististyle*) * which terminates in a spine (*appendage of the dististyle*). A small sclerite, the *coxite*, is hidden at the outer base of the basistyle The *interbasal fold* lies at the base of the basistyle where it forms an amphitheatre ventrally and laterally around the genital opening. This fold is of taxonomic importance because of the multiplicity of projections in which it manifests itself. In its most generalized form (*Theobaldia*, etc.) it exists as a conical lobe with stout spines (*basal lobe*) at the base of the basistyle, the ventral angles of each lobe meeting in the mid-ventral line In *Aedes* the fold manifests itself as a basal lobe and a more ventral finger-like elongation called the *claspette*; at the apex of the basistyle a dorsal *apical lobe* is present (*Theobaldia, Aedes, Ochlerotatus*) The *sub-apical lobe* of *Culex* is a projection of the interbasal fold that has migrated up the dorsal side toward the apex of the basistyle; no other manifestations of this fold are present in this genus. In *Anopheles* spp. setiferous lobes are present ventrally (*claspette lobes*) and lobe-like continuations are fused dorsally with the basistyles called the *parabasal lobes* (bearing heavy spines).

3. The external membranous projection of the ejaculatory duct, the penis, is protected laterally by chitinous plates, the penis valves In *Anopheles* these plates have fused into a slender elongate tube, the distal end of which may be ornamented by leaflets (of considerable taxonomic importance). In *Culex* and *Aedes* this structure is composed of tissue from the penis valves as well as from the inner surface of the basistyles, hence the term *phallosome* is more appropriate for these lateral plates of dual origin, which in *Culex* may be very grotesque because of multiplicity of lobes. *Parameres* are terms applied to the flaring, triangular plates on either side of the phallosome, which in reality are the walls of the cavity in which the phallosome may be sunk (absent in *Anopheles*).

4. The anal portion (tenth segment) of the terminalia (*proctiger*) is in the form of a membranous mound, lying within the ninth segment and dorsal to the genital opening. Supporting it ventrally are the chitinous *paraprocts*, which in some genera are tipped with heavy spines (*Culex*) or furcations (*Theobaldia*). A *ventral arm of the paraproct* extends ventrally around the phallosome, and a *lateral arm of the paraproct* sur-

* These are respectively the coxite and style of Edwards (1932, loc cit)

rounds the base of the proctiger. A chitinous plate occasionally found on the dorsal surface of the proctiger is the *epiproct*.

TABLE II

SYNONYMY OF TERMS USED IN DESIGNATING MALE TERMINALIA

Terms Adopted (after Freeborn 1924)	Terms used by Christophers 1933 [6] and Barraud 1934 [6]	Terms used by Edwards 1920 [7]
Proctiger	Proctiger	Anal lobe
Paraprocts	Paraprocts	10th sternite
Lateral arms of paraprocts	....	....
Ventral arms of paraprocts *(Culex)*	Basal lateral arm of paraproct *(Culex)*	Basal arm of 10th sternite
Epiproct	Dorsal plate of proctiger	10th tergite
Basistyle	Coxite	Side piece
Dististyle	Style	Clasper
Appendage of dististyle	Appendage of style	Claw
Basal lobe	Basal lobe	Basal lobe Claspette *(Taeniorhynchus)*
Claspette	Harpago	Claspette
Sub-apical lobe	Sub-apical lobe	Sub-apical lobe
Apical lobe *(Aedes)*	....	Apical lobe *(Aedes)*
Parabasal lobe	Parabasal lobe	Basal lobe
Phallosome	Phallosome	Mesosome
Paramere	Parameral plate	Paramere
Lobes of 9th tergite	Process of 9th tergite	Lobes of 9th tergite
9th sternite	9th sternite	9th sternite

Life history of mosquitoes.—All mosquitoes pass through the several stages of a complex metamorphosis—*egg, larva, pupa* and *adult*. (Fig. 68) The larvae are commonly known as *wrigglers* and the pupae as *tumblers*. Water in which to pass the larval and pupal stages is essential. Eggs in some species may be deposited on mud and the larvae in others may exist for several hours under similar conditions. Howard[8] states that "in no case, however, were we able to revive larvae in mud from which water had been drawn off for more than 48 hours, and after 24 hours only a small proportion of the larvae revived." Eggs, on the contrary, in some species may survive long periods of desiccation, notably

those of the yellow-fever mosquito which will hatch after being dry for a period of six months. According to Dyar,[9] the eggs of *Psorophora*, with their spinose protecting coat, are able to withstand desiccation on the dry ground for months or years, hatching with the advent of water.

Mosquito eggs are deposited either singly or in rafts (Fig. 69) on the surface of quiet pools of water and in some species along the margins, and even in fairly dry situations where pools may be formed later by rains or tidal action. The incubation period varies greatly with the species and temperature, from 16 to 24 hours in many of the Culicini to several months, i e., through the winter, in the snow mosquitoes, boreal Aedini, as well as in certain species of salt marsh mosquitoes, thus producing one brood annually.

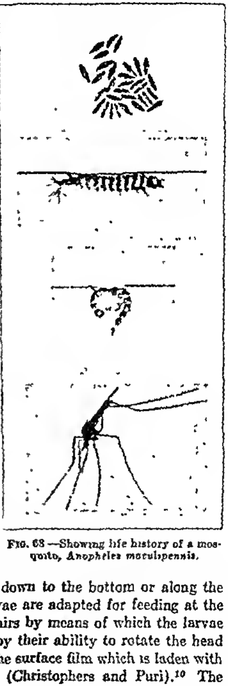


Fig. 68.—Showing life history of a mosquito, *Anopheles maculipennis.*

The larvae of the various many-brooded species, most commonly observed in rain barrels, watering troughs and similar situations, hang suspended diagonally from the surface by means of a prominent breathing siphon with head downwards as in the Culicini. The larvae of the tribe Anophelini lie horizontally just beneath the surface of the water, suspended particularly by means of palmate hairs (Fig. 69). The mandibulate larvae secure their food by browsing on microörganisms, both plants and animals. It is not difficult to observe the feeding habits of the larvae as they squirm about while breathing at the surface or wriggle down to the bottom or along the sides nibbling food. Anopheline larvae are adapted for feeding at the surface, indicated by the palmate hairs by means of which the larvae maintain a horizontal position and by their ability to rotate the head through 180° while feeding against the surface film which is laden with bacteria and other microörganisms (Christophers and Puri).[10] The

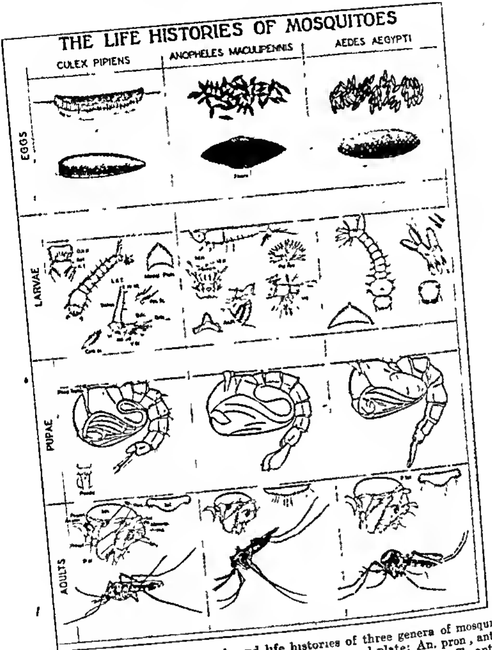


FIG 69.—Morphological details and life histories of three genera of mosquitoes: *Culex; Anopheles;* and *Aedes* Explanation: An Pl, anal plate; An. pron, anterior pronotal setae; Anl Sdl, anal saddle (dorsal plate); Ant, antenna; A. T., antennal tuft; Cmb sc, comb scale; D. Br., dorsal brush; D. H. H, dorsal head hairs; Hal., haltere; Hr. tft., siphon hair tuft; I. C. H., inner clypeal hair; L. A. T., lateral abdominal tuft, Mesemp, mesepimeral setae, Mn, mesonotum (tergum$_2$); O. C. H., outer clypeal hair, Pal. Hrs, palmate or float hairs (tuft); Pec. Sc, pecten scale; Pn, postnotum, Po. pron, posterior pronotal setae; Prea, prealar setae; Proeps, proepisternal setae; P. Spr., postspiracular setae; Resp Trump, respiratory trumpet; Scl, scutellum; Sp, spiracle; St. pl. sternopleural setae, V. Br., ventral brush (Adapted from various authors)

larvae grow rapidly during the warm summer, molting four times, the last molt resulting in the pupa. An average of seven days is required for the larval stage in several of our commoner Culicini under optimum conditions. The larval stage of the Anophelini requires a much longer time.

With the fourth molt the pupa or "tumbler" appears and this with remarkable rapidity. In this non-feeding though very active stage there is a pair of breathing "trumpets" situated dorsally on the cephalothorax. The pupa is remarkably active and sensitive to disturbances of the water, letting go suddenly and darting with a tumbling motion to shelter and after a few moments rising with little motion to the surface where the breathing trumpets break the surface film and contact with the air is reëstablished. The pupal stage is quite short, usually from two to three days.

In a series of experiments to determine the effect of various quantities of a given larval food on the development of a common species of fresh water mosquito in California, namely *Theobaldia incidens* (Thom.), the largest percentage of emergence was obtained when 2.5 grams of yeast were supplied per litre of distilled water. The egg rafts were first placed in the water, each raft in a separate container, hatching in about 2½ days The newly hatched larvae were thoroughly mixed and transferred in lots of 100 to battery jars containing one litre of water with a measured quantity of Fleischmann's yeast; pH readings were taken before and after the yeast was added and in all cases the pH readings were 6.6; daily pH readings were taken thereafter until all the mosquitoes had emerged, the pH remaining the same until pupation; the average minimum room temperature was 19.2° C and the maximum 24.4° C By far the largest percentage of adults, 88 per cent, was produced in the jar with 2.5 grams of yeast, 45 per cent males and 43 per cent females. The first molt took place on the fourth day, the second molt on the sixth day, the third molt on the ninth day, the fourth molt on the twelfth day when the first pupa appeared, and the first adult mosquito, a male, emerged on the eighteenth day, giving a total of about 21 days for the complete life history, including incubation period of the eggs. The complete record of the experiment is published elsewhere [11] When the temperature was maintained at 24° ± 1° C the life history was shortened to 12½ days—egg stage 24 hours, larval stage ten days, and pupal stage 36 hours.

Food habits of adult mosquitoes.—The mouth parts of male mosquitoes are not suited to piercing, hence they are not bloodsuckers. Their nourishment is normally derived from nectar and plant juices and other liquids. With the exception of a few species such as the plant feeding Megarhinini and the *Harpagomyia* which feed on regurgitated stomach contents offered by ants (*Cremastogaster*), all female mosquitoes are able to pierce the skin of animals and feed on blood. No doubt vast

numbers never have the opportunity to feed on blood. Many species are zoöphilic, feeding only on the blood of reptiles and amphibians, e.g. *Culex apicalis* Adams, and still others on the blood of larger mammals such as cattle. Species which feed on man by preference are known as anthropophilic.

Flight habits of mosquitoes.—Although most of the domestic species remain fairly close to their point of origin, i.e., within a distance of a few city blocks or half a mile, there are many species, particularly among the Aedini, which may travel many miles. In searching for breeding places of the common Culicini under urban conditions the point of origin will usually be found not far from the points of complaint.

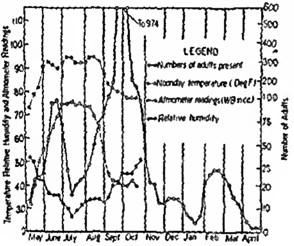
Salt marsh mosquitoes are often a source of great annoyance far from their breeding places and a knowledge of their migratory habits is important in mosquito control. *Aedes sollicitans* (Walker), an important salt marsh species of the Atlantic seaboard, is known to migrate at least forty miles. The migrations of *Aedes squamiger* (Coquillett) have been traced on the Pacific coast for a distance of 50 to 75 miles.[12] Males are seldom found far from their point of origin, although the males of *Mansonia perturbans* (Walker) are said to accompany the migrating females.

The flight range of *Aedes vexans* (Meig.) and *A. aldrichi* D. & K. has been studied by Stage, Gjullin and Yates [13] by using a stain, 1.5 per cent aqueous solution of methylene blue or eosine, applied with a hand compressed-air sprayer to newly emerged adult mosquitoes resting on vegetation near their breeding places. Mosquitoes were collected in this area at regular intervals until no more could be found. The collected specimens were killed and each tested with one or two drops of a solvent made of 3 parts glycerin, 3 parts 95 per cent alcohol and 1 part chloroform. The following results are recorded: (1) Both species and both sexes were dispersed in all directions, both with and against general wind currents, for a distance of about two miles. (2) Males moved away from the breeding areas more slowly than females. (3) Females of both species traveled one-half mile across part of the Columbia River (Oregon) within 24 hours after being stained. (4) One *Aedes vexans* (Meig.) female was recovered 46 days after being stained, three miles distant and across the Columbia River. (5) One *Aedes* sp. male was taken 24 days after being stained at a point five miles distant. This was the greatest distance for any positive flight record obtained. (6) The pests were abundant to a distance of fifteen miles from the breeding grounds and then diminished rapidly until at about thirty miles only one female was taken during a 10-minute search.

Longevity of mosquitoes.—Male mosquitoes usually remain alive but for six or seven days although *Anopheles pseudopunctipennis* Theob. males have been kept alive in our laboratories for over a month, and

Mayne [14] was able to keep an *A. punctipennis* Say male alive for 89 days and a female of the same species 231 days, while females with ample food may live for four or five months, particularly under hibernating conditions. During their period of greatest activity it is likely that the average lifetime of the females is not far from thirty days.

The staining experiments by Stage, et al. (loc. cit.), produced important data relative to longevity. Thus six *Aedes aldrichi* D. & K. females were taken 52 days after staining, one female of the same species 85 days after staining, one *Aedes vexans* (Meig.) female after 55 days, also under especially favorable conditions one 94-day old *A. aldrichi* D. & K. male was taken, and females of both *Aedes aldrichi* D. & K. and *A. vexans* (Meig.) were collected from 104 to 113 days after staining. The



latter species is said to have the greater maximum longevity by approximately 15 to 20 days.

Freeborn [15] has found that increased humidity has a protective influence on the longevity of *Anopheles maculipennis* Meigen kept at constant temperatures, but at a constant of 80° F. no amount of relative humidity can protect them for the full life span of a month. A relative humidity of 55 per cent insures the normal life span at 70° F. Freeborn points out that 55 per cent humidity involves a saturation deficiency of 3.6 grains per cubic foot by which can be expressed the drying power of the air in the absence of wind currents. A deficiency of 3.8 grains at 76° F. was tolerated for only three weeks instead of more than four. It is pointed out that the lethal effect may be caused by either a fatal temperature or by desiccation of the insect's body. With an increase of temperature or a

decrease in relative humidity the saturation deficiency increases and the demand on the insect's moisture content becomes greater. (Fig. 70.) The ability of a particular species to retain adsorbed water in the presence of existing saturation deficiencies undoubtedly explains the variability of resistance of the different species to desiccation, according to Freeborn. The length of life of *A. maculipennis* Meigen and other vectors of malaria has important bearing on their ability to transmit the disease.

Internal anatomy of mosquitoes.—To be prepared to study the relation of mosquitoes to such diseases as malaria and filariasis, the student should be familiar with their internal anatomy. The attention of the student is called particularly to the excellent treatise on the "Structure and Biology of Anopheles" by Nuttall and Shipley (1903) in the Journal of Hygiene, vol. iii, No. 2, pages 166–215.

The alimentary canal is separable into three regions, the *fore-*, *mid-* and *hind-gut,* each of which may be arbitrarily subdivided into more or less distinct divisions (Fig. 12). Thus the fore-gut consists of the sucking tube of the *proboscis,* the *pharynx,* including pumping organ and the *oesophagus* with its *diverticula* (three in number and generally known as food reservoirs); the mid-gut consists of a narrower anterior portion (false proventriculus) and a wider posterior portion (*stomach*) occupying the thorax and much of the abdomen, and limited posteriorly by the origin of the five *Malpighian tubules* which indicate the beginning of the hind-gut; the hind-gut is bent on itself several times and consists of the narrow, longer *ileum,* the *colon* and what is arbitrarily termed *rectum* indicated by the presence of *rectal papillae.*

The *salivary system* consists of two sets of salivary glands (right and left), three glands to each set. These organs are situated ventrally in the thorax near the neck. Each set of glands empties into a duct which combines with the opposite one to form the common salivary duct. This common duct empties its contents into the pharynx through the salivary receptacle close to the base of the proboscis.

The *reproductive system* of the female mosquito occupies the posterior portion of the abdomen and comprises a pair of *ovaries* joined by a pair of oviducts terminating in the *vagina* which opens ventrally in a depression of the ninth sternite; *spermathecae* are present (one to three, depending on the species). The spermathecae of an impregnated female contain myriads of spermatozoa, and the ovaries when mature occupy the larger part of the abdomen.

Tribe Megarhinini

Characteristics.—The members of the tribe Megarhinini are tropical in distribution; usually highly colored; they are day fliers and both sexes

are flower-feeders and do not suck blood. The basal half of the proboscis is stout and rigid, while the distal portion is flexible, which accounts for the curious hook-like position of the proboscis when at rest. The palpi vary in length from one-fourth the length of the proboscis to nearly the same length. The huge larvae are predaceous and cannibalistic. The mouth parts are particularly adapted for capturing prey.

The eggs are deposited singly and Edwards states that most species breed in small confined collections of water, such as may occur in bamboo stems, tree holes, pitcher plants and the like.

Edwards lists 52 species, of which two species are said to occur in North America, *Megarhinus rutilus* Coq. and *M. septentrionalis* Dyar and Knab. The giant species *Megarhinus inornatus* Walker was introduced from New Britain into the Hawaiian Islands [16] for purposes of mosquito control.

Tribe Culicini

Characters.—All members of the tribe Culicini have the scutellum trilobed with each lobe bearing bristles, but areas between lobes without bristles (Edwards). The abdomen is blunt and completely clothed with broad scales which nearly always lie flat; the pulvilli are broad and distinct; post-spiracular bristles absent; the larvae have a prominent siphon with well developed pecten (Fig. 69), and usually numerous hair tufts on the siphon. The eggs are usually deposited in mass-like rafts on the surface of the water.

The Tribe Culicini, exclusive of the Aedini, which are separated from the Culicini for the purposes of this book, includes more than 500 species distributed among more than twenty genera, of which the genus *Culex* alone contains 315 known species.

Culex pipiens Linnaeus. This is the common house mosquito or rain barrel mosquito of eastern North America, the Pacific coast, Canada, Europe and portions of South America. It is grayish brown to brownish gray in color. The basal white bands on the abdomen join lateral basal triangular patches. This mosquito, a domestic species, lays its eggs in rafts on water, in rain barrels, tanks, cisterns, catch basins, and other small collections of water. It has a predilection for polluted waters. Where breeding places are favorable it may occur in enormous numbers and invades houses freely. Because of its vicious bites and high-pitched, tantalizing hum continued late into the night, it may be a terrific pest. Although greatly influenced by temperature the life history requires but about ten days under warm summer conditions, egg stage 18 to 24 hours, larva about seven days and the pupa about two days.

Woke [17] fed 38 *Culex pipiens* Linn. on man, and these mosquitoes deposited 29 egg masses, totaling 2,118 eggs, or an average of 73 0 eggs per

mass. At the same time 39 females fed on a canary deposited 22 egg masses, totaling 4,473 eggs, or an average of 203.3 eggs per mass. Over twice as many eggs per mass or per milligram of blood ingested were produced by mosquitoes fed on canary blood as were produced by mosquitoes fed on the blood of man.

Culex tarsalis Coquillett is widely distributed throughout the western United States as far east as Illinois, reaching its greatest development on the Pacific coast from Mexico to British Columbia even at elevations of over 7,000 feet. Although normally not obnoxious it may at times attack humans. It breeds prolifically in almost any ground pool, no matter how foul, particularly those of a sunlit and a permanent nature, although breeding may take place in clear shady woodland pools. It is a rapid breeder with a life history similar to *Culex pipiens* Linn. which it also resembles in color, i.e., it is grayish brown to black in general appearance. The ventral abdominal black markings show an inverted V. Dorsally the black abdomen is marked with white basal bands and the black legs have white banded tarsi.

Theobaldia incidens (Thomson), like other members of this genus, partakes of characters which would place it in either of the tribes Culicini or Aedini, but for practical purposes, based largely on breeding habits, the members of this genus are placed in the tribe Culicini. In this genus (*Theobaldia*), which includes over six North American species, the post-spiracular bristles (Fig. 69) are absent and in the females of at least Pacific coast species the anterior and posterior cross-veins tend to lie in one line. In *Theobaldia incidens* (Thom.), a western species (west of the Rocky Mountains), the wings are spotted. It breeds throughout the year, where temperature permits, in all sorts of permanent pools and is a common domestic species. It lends itself particularly well to laboratory experimentation. The life history of this species is described earlier in this chapter. *Theobaldia maccrackenae* (Dyar and Knab), a Californian species, resembles *T. incidens* (Thom.) quite closely except for differences in the male terminalia and that the wing spots are smoky because of the adjacent brown-stained areas and the scaly condition of the cross-veins [naked in *T. incidens* (Thom.)].

Theobaldia inornata (Williston) is found throughout the United States and southern Canada. The wings are broad and clear, the cross-veins are scaled, and the very short black palpi have white scales at the tip. In breeding habits it resembles *T. incidens* (Thom.).

Theobaldia impatiens (Walker) occurs throughout the northern part of North America, though not numerously. It resembles *T. inornata* (Will.) except that the cross-veins are bare of scales and there are indistinct spots at the vein forkings. *Theobaldia inornata* (Will.) and *T. impatiens* (Walk.) are separated from *T. inciden*. (Thom.) and *T. mac-*

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Characteristics.—Ordinarily the Aedes mosquitoes are included in the tribe Culicini, but because of their remarkable breeding habits and other striking characteristics the author has taken the liberty to set the *Aedes*, of which there are about 500 species, apart as a separate tribe, the Aedini. More than half of all the species of mosquitoes in North America belong to the genus *Aedes*.

Like the Culicini the Aedini have a trilobed scutellum. Most of the species as Edwards points out have the claws toothed in the female, post-spiracular bristles present, the pulvilli absent or hair-like and the female abdomen tends to be more pointed and the cerci longer than in other groups. The larvae have short siphons bearing one pair of postero-ventral hair tufts, and nearly always a distinct pecten (Fig. 69). The eggs are deposited singly on the surface of the water, on mud or even in situations where there may be little moisture but where submergence may follow. The females of all species bite, many of them viciously. Many species are diurnal in biting habits, most of them biting toward evening.

Among the forty species of *Aedes* in North America are *Aedes aegypti* (Linn.), the yellow-fever mosquito; *A. vexans* (Meigen), the vexatious mosquito, breeding in flood water; *A sollicitans* (Walker), the famous "New Jersey" mosquito, breeding in salt marshes; *A. dorsalis* (Meigen) breeding in salt marshes, also fresh water, particularly on the Pacific coast; *A. squamiger* (Coquillett) breeding in brackish water on the Pacific coast; *A. varipalpus* (Coquillett), a Pacific coast tree hole mosquito; *A. cataphylla* Dyar, a Rocky Mountain snow mosquito; *A. communis tahoensis* Dyar, a common Sierran snow mosquito.

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eggs may remain unhatched for many months in situations from which water is excluded. Development after hatching is rapid, emergence of the adult mosquitoes may be within eight or nine days.

Aedes squamiger (Coquillett) is restricted to the Californian seacoast from San Francisco Bay to San Diego, breeding in salt marsh pools that are fed by fresh water from the winter rains. Like *A. dorsalis* (Meig.) it is a fierce day biter, rather worse toward dusk, and travels great distances. It is known as the gray salt marsh mosquito. The vestiture is characteristically composed of large scales. The proboscis is uniformly black scaled. Its egg-laying habits are similar to *A. dorsalis* (Meig.); there is, however, but a single brood coming very early in the spring, as early as February.

Aedes taeniorhynchus (Wiedemann) is a typical salt marsh breeder distributed along the coastal area of the United States northwards to Connecticut on the east coast and Santa Barbara on the west coast. It is the brown salt marsh mosquito; its proboscis is distinctly white banded. It is a fierce day biter and its egg-laying habits are similar to *A. dorsalis* (Meig.) and *A. squamiger* (Coq.). There are monthly broods throughout the summer. Development is exceedingly rapid, the larval stage may require but four days, the adults emerging in from eight to ten days.

Aedes sollicitans (Walker), the pestiferous salt marsh mosquito of the Atlantic coast, breeds from Maine to Florida and thence west along the Gulf of Mexico to Texas. There are many broods, and in its southern range breeding may be continuous.

The numbers of larvae appearing in certain pools is almost unbelievable. Smith [18] states:

"I have found pools so crowded that an estimate of 100 wrigglers in an area [illegible]

[illegible] incredible they [illegible]

[illegible]

Flood-water Aedes.—*Aedes vexans* (Meigen) is a typical flood-water mosquito having practically a world-wide holarctic distribution. It is one of the fiercest day biters and exceedingly abundant—it is truly a vexatious mosquito. It breeds in greatest numbers along the edges of rivers subject to overflow, and like other *Aedes* species lays its eggs along the muddy edges of receding pools where they hatch during the same season when water due to intermittent flooding or freshets reaches them. There may thus be several broods where flooding occurs due to melting mountain snows or thunderstorms, or there may be only one brood where there is a single spring flood. It is a rapid breeder and migrates many

miles. It varies in color from brown to gray; the tarsi are basally narrowly banded; the wings are uniformly brown.

Aedes dorsalis (Meigen), already referred to as a salt marsh breeder, is also a prolific breeder in open flood-water pools, particularly in irrigated pastures after flooding and in drainage pools due to excess water. Where early flood waters occur along wooded river courses the single-brooded *Aedes vexans* (Meig.) dominates, but as the season advances *Aedes dorsalis* (Meig.), a many brooded species, supersedes it in these areas, but breeds particularly in open pastures where the temperature of the water is high. At 99.5° F. (in water) we found enormous numbers of larvae completing their cycle in about six days.

Tree hole mosquitoes.—Although the habit of breeding in tree holes occurs in various species belonging to genera other than *Aedes*, e.g., *Anopheles barberi* Coquillett, etc., there are a number of typical tree breeders in the Aedini, notably *Aedes varipalpus* (Coq.) a Pacific coast species, *Aedes triseriatus* (Say) of the eastern United States, *Aedes luteocephalus* Newstead, Ethiopian, *Aedes simpsoni* Theobald, Ethiopian, and others.

Aedes varipalpus (Coquillett) has bright white markings on the legs at both bases and apices of the tarsal segments and many white or silvery scales distributed over the body so as to give the vestiture a silver mottled appearance. It is one of our smallest mosquitoes but a fierce biter. This Pacific coast species deposits its eggs on the sides of tree holes, notably holes in live oaks (*Quercus agrifolia*), also California laurel (*Umbellularia californica*) and valley oaks (*Quercus lobata*). Freeborn[19] states that the eggs "hatch whenever they are wet by the rising waters. There is some evidence that the eggs may drop off after a period of desiccation or, as an alternative method, the larvae may hatch without the intervention of actual wetting and fall into the water below. The straw colored larvae with bright brown heads and enormously developed gills swim about their secluded medium with snake-like movements, but spend most of their time with their heads and thoraces buried in the silty deposit at the bottom of the tree holes. . . . The developmental period is extremely long, lasting from one to seven months. Although there is an intermingling of the broods, there are two pronounced peaks, one in the early summer and another in the fall. The fall adults deposit eggs which produce the larvae that over-winter."

Psorophora ciliata (Fabricius) is one of eight species of this genus in the United States. It is a widely distributed species in the eastern part of the United States, southeastern Canada and South America. Matheson states that it is a vicious biter, breeding in temporary ground-puddles and the larvae are predaceous, feeding on the larvae of other mosquitoes.

Psorophora columbiae (Dyar and Knab) is one of the smaller members of this genus. The larvae, which are non-predaceous, live in temporary rainpools and overflow irrigation water. The adult has a very speckled appearance, the first tarsal segment has a white mesial band and the remainder are banded basally. Its range includes Cuba, Bahamas, and the United States from New York to Texas.

In 1932 this species is reported to have caused great loss to livestock in the Everglades section of Florida. The U. S. Insect Pest Survey Bulletin (Vol. 12, No. 10, p. 428) describes the plague: "by evening of that day the buzzing was as loud as that of a swarm of bees. During the night livestock could be heard running and thrashing in the underbrush, and on the morning of September 6, dead animals were found throughout the section. The recorded mortality was 80 head of cattle, 3 horses, 1 mule, 67 hogs, 20 chickens, and 2 dogs. Post mortem examinations showed no mosquitoes in the respiratory apparatus, indicating that the animals died either from loss of blood, nervous exhaustion, or the effects of some toxin." The milk supply was also greatly reduced during the four days of the infestation.

Boreal Aedes or snow mosquitoes.—An interesting group of *Aedes* consists of the so-called snow mosquitoes which appear in the early spring in the high mountains and northern ranges of distribution, breeding in the pools left by the melting snow. These *Aedes* have but one generation and appear in enormous swarms in the higher elevations and northern ranges much to the dismay of the huntsman and alpine traveler. These mosquitoes have been collected in many localities in the Sierra Nevada by the writer and the following quotations are taken from an interesting account of the same by Dyar.[20]

"At an altitude of 6,000 feet, pupae were abundant May 25 and by the first week in June the breeding was complete; even the pools that still contained water or had only just thawed out were empty. Adults appeared by the first of June, and by the 15th the woods were filled with them in all directions.

"Speaking especially of the Fallen Leaf Lake region (vicinity of Lake Tahoe) a region in the heart of the Sierras to the north of the high peaks and on the eastern side of the divide, *A. (communis) tahoensis* is the commonest and earliest species, found everywhere, both in the hills and the pines in level country. It breeds in the earliest pools of clear water held in rocky land, its home being in the ma . . . It was common in the early . . . the only species present. It . . . Dispersal of the adults was in general downward, they being abundant in the pines at Tallac on June 17, though no breeding places were near. *A. cataphylla* is less abundant and less widely dispersed at Fallen Leaf. It was commonest at the foot of the trail to Angora Lakes at the head of the lake, rare at the outlet of the lake and absent at Tallac on Lake Tahoe. *A. hexodontus* breeds in early pools, but especially those of a marshy character, larvae being taken from hoofprints of cattle in the edge of a marsh. The adults were well distributed and toward the end of June replaced *A. (communis) tahoensis* as the dominant species. *A. ventrovittis* is a

rare species, taken only at one place near the outlet of Fallen Leaf Lake and then in small numbers. It is presumably a marsh breeder, though the larvae were not found. *A. palustris* breeds in open grassy marshes, not in large numbers. Dispersal was general, adults being taken everywhere, although seldom commonly. *A. increpitus* is the slowest breeder of any of the early species, the larvae lingering after all the others are gone, frequently in the same pools. They were abundant at the outlet of Fallen Leaf Lake with a downward dispersal, the adults being common at Tallac, about 2 miles from the breeding places, while only found a quarter of a mile up the lake and many days later.

"The seasonal appearance of these mosquitoes varies with the altitude in the ratio of about a month in time to 1,000 feet of elevation. At Yosemite, at about 5,000 feet, all the species were about a month earlier than at Lake Tahoe, at 6,000 feet, while at Summit, at 7,000 feet, they were still another month later, larvae and pupae of *tahoensis* and *hexodontus* being taken there on July 2, 1916, about the same stage that they were taken at Fallen Leaf on June 1, 1916."

At an elevation of about 10,000 feet the author encountered a veritable plague of *Aedes ventrovittis* Dyar and *A. communis tahoensis* Dyar along the shores of Young Lakes in the Sierra Nevada Mountains July 22–27, 1936. Larvae and pupae were still present in small pools of snow water along the shores of the lakes. Apparently only certain pools were infested.

Yellow-fever mosquito.—Although the yellow-fever mosquito will long be known under the specific name of *Stegomyia fasciata* (Fabr.) the species is apparently correctly designated as *Aedes aegypti* (Linn.), having stood for several years under the name of *Aedes calopus* (Meig.) and *Aedes argenteus* (Poiret). This species is widely distributed within the limits of 40° N. and 40° S. latitude, but is highly susceptible to temperature variations. According to Hindle [21] it soon dies in the open air at a temperature of 7° to 8° C., succumbing in a few seconds to an exposure of 0° C., and 37° C. is rapidly fatal. Furthermore, it does not thrive in dry hot climates. The adult insect is beautifully marked with silvery white or yellowish white bands and stripes on a nearly black background, whence the name "tiger mosquito." It has a "lyre-like" pattern dorsally on its thorax, i e., two outer curved yellowish white lines and two median parallel lines. The legs are conspicuously banded and the last joint of the hind leg is entirely white. The head is covered with broad flat scales with only a single row of upright forked scales.

The yellow-fever mosquito is a typical domestic species seldom found far from buildings. Many observers believe it to be a day-flying and day-feeding species, but this habit apparently is restricted to the younger individuals up to six or seven days after emergence, or rather until a meal of blood is secured, when the insect becomes nocturnal. Howard observes that "it prefers the blood of white races to that of dark races, and attacks young, vigorous persons of fine skin and good color in preference to anemic or aged people."

The eggs of the yellow-fever mosquito are deposited singly, are dark

in color and each egg is surrounded by air cells (Fig. 69). Comparatively few eggs are deposited at one laying, and while there may be several layings, the average total is probably about 100.

Unlike the eggs of most species these can withstand desiccation to a very marked degree, some authors declaring that this is possible for several months. Ordinarily the eggs hatch in about 48 hours.

The larvae are quite robust, the breathing siphon is comparatively short and heavy and black (Fig. 69), and their position in the water is almost vertical, considerably more so than other culicine species. The larval stage is ordinarily passed in about 9 or 10 days under average conditions.

The pupae have broadly triangular breathing trumpets. Only about 36 hours is spent in the pupal stage.

According to Howard the shortest period of development from egg to imago observed by Reed and Carroll in Cuba was nine and one-half days, viz.: egg stage, two days; larval stage, six days; pupal stage, 36 hours. From this very short period the time ranges from 11 to 18 days according to the same author.

The yellow-fever mosquito breeds by preference in artificial pools of rain water. (It is known, however, at times to breed naturally in brackish water.) Rain-water barrels, tanks, cisterns, tin cans, urns, etc., provide suitable places, also water collected between the leaves of certain members of the Agave family; ornamental banana palms are often a great menace in this respect.

Woke [22] has shown that *Aedes aegypti* (Linn.) fed on frog-blood and turtle-blood produced viable eggs, and that the larvae developed normally and produced normal adults.

Although *Aedes aegypti* (Linn.) is undoubtedly the most important vector of yellow fever under natural conditions because of its domestic breeding habits, there are nevertheless a dozen other species which are able to transmit the disease from monkey to monkey by the bite.[23] Among these are the African species *Aedes luteocephalus* Newstead, *A. stokesi* Evans, *A. vittatus* (Bigot), *A. africanus* Theobald, *A. simpsoni* Theobald; *Aedes fluviatilis* (Lutz), and *A. scapularis* (Rondani) of South America, as well as *Aedes albopictus* (Skuse) and (*A. scutellaris* Theob.) of the Far East.

Tribe Anophelini

Characters.—The following characters are usually employed to characterize the tribe Anophelini; palpi of both sexes usually about as long as the proboscis, scutellum (Fig. 69) evenly rounded (except in *Chagasia* where a slightly trilobed condition occurs); mandibles and maxillae of the females well developed and toothed; legs very long and slender, r

distinct tibial bristles, no pulvilli; abdomen without scales, or at least with the sternites largely bare (Edwards); wings usually with distinct markings.

The tribe Anophelini has been divided into numerous genera such as *Myzorhynchus, Arribalzagia, Argyritarsis, Neomyzomyia, Myzomyia,* and more than thirty others. Edwards and other culicidologists have reduced the number of genera to three—*Chagasia* (scutellum slightly trilobed), *Bironella* (scutellum evenly rounded, wing with stem of median (M) fork wavy), and *Anopheles* (scutellum evenly rounded, wing with stem of median (M) fork straight).

There are three species of *Chagasia*, all of tropical America. The genus *Bironella* includes but two species, both of New Guinea. The genus *Anopheles* includes about 160 species, only nine of which occur in North America, namely *Anopheles maculipennis* Meigen, *A. quadrimaculatus* Say, *A. punctipennis* (Say), *A. pseudopunctipennis* Theobald, *A. crucians* Wiedemann, *A. walkeri* Theobald, *A. barberi* Coquillett, *A. atropos* Dyar and Knab, and *A. albimanus* Wied.

The common species rest with the proboscis, head and abdomen nearly in a straight line and when resting have the appearance of a splinter lifted at an angle from a surface. (Fig. 68) In exceptional cases, as in *Anopheles culicifacies* Giles of India the resting position is Culex-like. Hoffman [24] states that *A. grabhamii* Theobald rests with its body almost at a right angle to the vertical surface. The hum of anophelines is distinctly low pitched and almost inaudible unless they are close to the ear or in a bottle. Although most of our common anophelines are not strong fliers and usually take to cover even in a moderate breeze, there are nevertheless striking dispersal flights in several species which may carry numerous individuals ten or more miles from their breeding places. In California, *Anopheles maculipennis* Meigen engages in an annual dispersal flight during the last two weeks in February, during which time much territory is invaded and eggs are deposited. As a rule this invasion is futile because of unfavorable conditions, but in the main the flight favors the preservation and spread of the species. During this flight the mosquitoes bite by day even in broad sunlight.

Although some individuals overwinter in the larval stage buried in mud and debris at the bottom of certain pools, the usual method of overwintering is in the adult (females only) stage. This is not generally a true hibernation since the females bite frequently on warm days or in heated buildings and change their resting places from time to time throughout the winter (Freeborn 1932, loc. cit.)

Mating and oviposition.—Fertilization of the females takes place almost immediately upon emergence. The males emerge first and may be seen dancing over or near the breeding places in small swarms apparently

awaiting the appearance of the females, which dart into the dancing swarm and mating occurs. This type of mating requiring wide spaces is known as *eurygamous*, while those forms such as *Anopheles* (*sacharovi* Favr.) *elutus* Edwards which mate in confinement in a small space are known as *stenogamous*. Overwintering females are fertilized by the last brood of males during the autumn and the eggs are deposited soon after the spring dispersal flight. In certain localities at least there is a period when the species exists only in the larval stage, all the adults having died after egg deposition. There is probably only a single laying at this time.

Under laboratory conditions the great majority of eggs are deposited between sunset and eleven in the evening (vicinity of Chico, California, May to August), although our records show layings later at night and a few during late afternoons of highly overcast humid days. The average number of eggs deposited by *Anopheles maculipennis* Meig. is slightly in excess of 200, with 385 as the maximum for one laying.[25] The same average and somewhat smaller total number for one laying was observed for *Anopheles punctipennis* (Say); a maximum of 321 having been observed with an average of 203.[26] During 1937 the largest number in one batch for this species was 352, observed by Aitken. One *A. punctipennis* (Say) female deposited 500 eggs in our laboratory in four layings from Mar. 2 to 22, 1938. For *Anopheles pseudopunctipennis* Theobald a maximum of 283 was observed with an average of 151. At least three batches of eggs may be laid during the lifetime of a female. It is of interest to note that in one of our observations a female *A. maculipennis* Meig. deposited 174 eggs in 19 minutes, an egg every six to seven seconds with intervening periods of rest. During the entire operation the female resting on the surface of the water remained motionless except for the monotonous jerking of the abdomen when the egg was released. The eggs fell in a heap beneath the insect, pearly white in color, toppling over and forming beautiful geometrical patterns and becoming deep brownish black in about 45 minutes.

Egg characters.—The characters of anopheline eggs used in classification are presence or absence of floats, position and length of the float, presence or absence of frill, also pattern. Christophers and Barraud[27] classify anopheline eggs as of four types:

1. Eggs probably of primitive type with full-float surrounding egg,
2. Eggs with terminal frill (*pseudopunctipennis* of Herms and Freeborn),
3. Whale-back eggs with floats separated from dorsal surface,
4. Various types of boat-like eggs with floats touching margin of dorsal surface.

The egg of the Californian *A. maculipennis* Meig. (Fig. 71) is fusiform, slightly rounded at each end and tapering to the extent that one

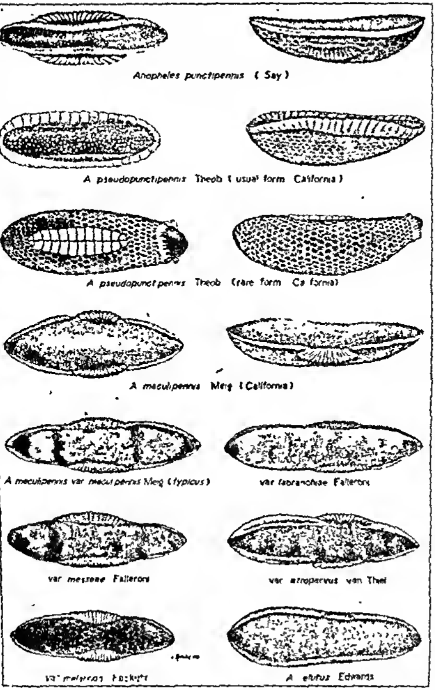

FIG. 71.—Eggs of anopheline mosquitoes, including racial forms. (European races of *A. maculipennis* redrawn after Hackett.)

end is slightly hroader than the other (Herms and Frost 1931 loc. cit.). The upper surface is flattened with a slight longitudinal concavity, while the lower surface is broadly convex, the convexity hecoming more pronounced at the hroad end of the egg. The upper surface is granular, hordered by a laterally striated frill 16μ in width, except at the floats, while the lower surface shows, under proper light, a silvery reticulation. Medianly placed are two roughly oval lateral floats, each divided in a majority of casea into twelve scalloped compartments. The larger part of the area covered by these floats is on the lateral faces of the egg, hut they project dorsally over the margins which are described as "gunwales" rather aptly hy one author who likens the egg to a hoat. The eggs range in length from 592 to 656μ. The floats vary in length from 122 to 224μ.

Falleroni, Martini, Hackett and Missiroli (see Hackett 1934 [28] and Hackett and Lewis 1935 [29]) have shown that *Anopheles maculipennis* Meigen actually comprises seven races in Europe which may he distinguished primarily only by egg patterns, namely var. *melanoön* Hackett, var. *messeae* Falleroni, var. *typicus* Meigen, var. *atroparvus* van Thiel, var. *labranchiae* Falleroni and var. *subalpinus* Hackett and Lewis; another, *elutus*, which is solid leaden colored and is considered as a valid species, *Anopheles elutus* Edwards. (Fig. 71.)

The eggs of *A. punctipennis* (Say) resemhle those of ths Californian *A. maculipennis* Meig. with these exceptions: the "frill" extends along the margins of the egg without interruption at the site of the floats which are located on the upper portion of the ventral surface, and extending farther along the sides of the egg, are a greater numher of compartments ranging from 16 to 22 wbich do not converge in fan-wise fashion as in *maculipennis*.

The eggs of *Anopheles pseudopt*[illegible] in at least two different forms in California. [illegible] eggs as having the upper surface [illegible] longitudinally although the lower surface shows a marked convexity. Both ends of the egg are rounded, one being considerably hroader than the other. The floats are represented hy a fusiform closely appressed area, approximately 270μ long, lying on the dorsal side of the blunt end. This area is divided medianly by a line which is assumed to he the line of contact of the two floats that bave been forced up from the sides. Lateral lines mark off each longitudinal balf of the area into twelve sections representing the original compartments of the lateral floats. This area is so appressed tbat its position is not distinguishable from a lateral view. Near the narrow end of the egg the membranous covering flares out from the hody of the egg to form a translucent, striated collar which completely encircles the end, with the exception of a triangular incision down the dorsal median line in a manner whicb reminds one of an over-

sized dress collar. (Fig. 71.) The egg hangs at an angle in the water, supported by surface tension on the "collar." The eggs ranged in length from 512 to 528μ. Rozeboom [30] states that the eggs of *A. pseudopunctipennis* Theobald in Panama resemble the eggs of the Californian species as described by Herms and Freeborn, except that in the Panamanian form the floats are large and have many float ridges; the collar-like frill being identical. The Panamanian eggs ranged in length from 480 to 575μ, the mean being 520μ.

A second form of *A. pseudopunctipennis* Theobald egg was described by Herms and Frost (loc. cit.) viz.: floats are not only present but completely encircle the egg which lies flat upon the surface of the water with the floats extended in nearly every instance. (Fig 71.) The floats average from 45 to 47 in number, and from 15 to 25μ in width, being wider along the sides of the egg and narrowed at the ends. The length of the eggs over all ranged from 510 to 544μ.

"Anophelism without malaria."—Hackett (Malaria in Europe) in Chapter II on the "Malaria Puzzle in Europe" points out that because of the presence of anophelines in great numbers in areas without malaria, various theories have been advanced to explain this. "Anophelism without malaria" is an expression now commonly used in the study of malariology. Hackett refers to such theories as (1) robust mosquitoes produced under unusually favorable conditions are unsusceptible to plasmodial infection (Alessandrini); (2) brackish water breeds robust anophelines which easily become infected, live long and are therefore most dangerous (Grassi); (3) coumarin, the active principle in a type of clover, *Melilotus altissimo*, present in clover honey, either kills sporozoites in the mosquito glands or protects the mosquito against infection (D'Herelle); (4) adaptation of the maxillary tooth formula to feeding habits of the mosquito,[31] i.e., increase in the number of teeth might indicate an adaptation to tough skins of larger domestic animals (zoöphilism); when the average number of teeth (maxillary index) was between fourteen and fifteen this race fed constantly on domestic animals and did not feed on man, those feeding on human blood having an index of 14 or less (Roubaud); (5) gonotrophic dissociation refers to undeveloped ovaries in the female anopheline, following a blood meal, e.g., a strain of anophelines which passes the winter in warm stables and houses where there is plenty of available food, yet is not stimulated to oviposition (Swellengrebel). Normally the ovaries of anopheline females develop following a blood meal; also the females usually undergo true hibernation without a blood meal. Thus *A. maculipennis* variety *atroparvus* van Thiel resolves itself into two strains one of which shows gonotrophic dissociation and is the explanation of so-called "malaria houses," i.e., when this strain "takes up winter quarters in a house, it lives upon the family; and if the mosquito

should he infected or some one in the house should be a carrier, by spring most of the family will have contracted malaria and will have passed it on to the rest of the anophelines sheltering in the house." (6) Geographic subspecies distinguished by egg types, seven being recognized, indicating wide divergence in feeding and breeding habits; barred eggs of cattle feeders, and eggs of more uniform pattern of malaria vectors and brackish water breeders (Falleroni and Martini, Missiroli and Hackett).

Breeding habits.—The breeding habits of anophelines differ considerably for even very closely related species, e.g., the American *Anopheles maculipennis* Meigen and *A. quadrimaculatus* Say, both four-spotted anophelines separable with accuracy only on differences in male terminalia, have widely different breeding requirements, the former at least in California breeding largely in open sunlit shallow seepage water, and the latter in impounded water with floating debris and plants; the European races of *A. maculipennis* Meigen already referred to emphasize the need of accurate knowledge; *Anopheles crucians* Wiedemann breeds in both fresh and saline water; *A. atropos* Dyar and Knab and *A. ludlowi* Theobald are salt-marsh species; *A. barberi* Coquillett breeds in tree holes; *A. punctipennis* (Say) prefers cool, clear, shady pools; *A. minimus* Theobald is a flowing stream breeder.

The following example illustrates the very great importance of knowledge of breeding habits in conducting malaria control operations. Williams[32] points out that in the Federated Malay States *Anopheles umbrosus* Theobald is the vector of malaria in the coastal plain, breeding in practically stagnant water densely shaded by mangrove. Its production is controlled, as Williams points out, by clearing the swamps and letting in the brilliant sunshine, or by cutting ditches and confining the water to definite channels. The same type of work when practiced on high inland plateaus increases the malaria rate, because here the vector is *Anopheles maculatus* Theobald, which prefers the quiet edges of trickling streams in the open sunshine.

Anopheles minimus Theobald is the principal vector of malaria in the Philippines. It breeds in small flowing streams in the foothills. Russell[33] points out how this mosquito may be controlled by periodically closing and opening a dam situated about halfway along the length of the stream "Observations show that this simple procedure done twice on one day a week brought about a marked reduction in larvae both above and below the dam, probably by stranding above and by flushing below."

An unusual situation is reported for *Anopheles sergenti* (Theobald), a north African and Palestinian species, in which the larvae were found in small pools and springs among stones at the edge of the lake (of Tiberias). The larvae were often under the stones and not easily found (Buxton 1924[34]).

Life history.—Although there is much variation in the life histories of the species of *Anopheles* mosquitoes (Fig. 68) as well as considerable variation within the species due to temperature and other factors, the length of time required for development from egg to adult is generally longer than in other genera.

Incubation period.—In a series of tests in which about 20,000 eggs of *Anopheles maculipennis* Meig[35] were used the incubation period at room temperature of 70° F. ± 3° was about 72 hours. Under field conditions the incubation period ranged from two to four days, with an average of 2.5 days, under which conditions the incubation period of *Anopheles punctipennis* (Say) ranged from two to six days with an average of 3 2 days.

The eggs of *A. maculipennis* Meig removed from the water and dried at temperatures of 74° F. and 65° F. remained viable after a period of desiccation not over 72 hours No hatching was obtained from eggs of *A. punctipennis* (Say) after 24 hours' desiccation.

Larval period.—Hatching generally took place in the experiments cited during the evening and night. With yeast as food in distilled water at pH of 6.6 to 7.6 the larvae of *A. maculipennis* Meig. reached the pupal stage in fifteen to sixteen days.

Pupal stage.—The pupal stage requires about three days. Thus the entire life history from egg to adult in *A. maculipennis* Meig. under experimental conditions requires about twenty-one to twenty-two days; the same is true for *A. punctipennis* (Say) and *A. pseudopunctipennis* Theob Under field conditions this period may be considerably prolonged. Adult mosquitoes reared in the laboratory did not begin oviposition until thirteen to fifteen days after receiving a blood meal.

The life cycle of *Anopheles albimanus* Wiedemann, the important vector of malaria of the Panama Canal Zone, has been carefully studied by Rozeboom.[36] With room temperature between 27° and 32° C. and water temperature for larvae from 21° to 27° C., and eggs and pupae at 27° to 30° C., the entire cycle (egg to adult) required from 18 to 24 days, an average of three weeks A period of seven days, or a little over, was necessary for the development of the ovaries, an average of 435 eggs being deposited; the incubation period was 40 to 48 hours; the larval stage required from 6 to 22 days, usually 8 to 13 days in hay infusion water; the pupal stage took 30 to 33 hours; the longest observed adult life of a female was 31 days, and of a male, 27 days.

Anopheles quadrimaculatus Say occurs in the United States from Mexico to Canada throughout the Mississippi Valley and east to the Atlantic. It is the chief vector of malaria in the eastern, central and southern United States. The wings have four distinct spots. According to Williams:[12]

ten annual broods, the first appearing from twenty to thirty days after the last frost, and the last brood, the tenth, if there is favorable weather in December. January and February he states are the only months when no broods emerge.

Anopheles maculipennis Meigen (Figs. 72 and 73) is a widespread species in Europe and occurs along the northern border of the United States and Canada, dipping southerly along the Pacific coast into Mexico. Much of the literature dealing with this species on the Pacific coast is published under the name *Anopheles occidentalis* D. and K. This species also has four spots on the wings, resembling *A. quadrimaculatus* Say so closely that an examination of the male terminalia must be used for differentiation. It invades houses freely. In California it breeds primarily in fresh clear seepage water, particularly the result of leakage from

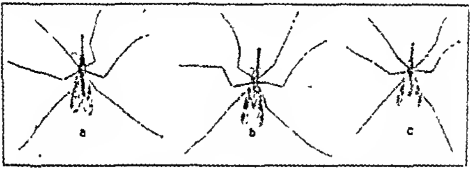

FIG. 73—Californian Anopheles: (a) *A. maculipennis;* (b) *A. punctipennis;* and (c) *A. pseudopunctipennis.*

irrigation ditches, water pipes, and seepage from rice fields (Fig. 91) and streams. It is commonly associated with irrigation developments, hence is most frequently found in California where there is farming under irrigation. (Figs. 80 and 81.) It may breed in rice fields when, because of porous soil conditions, fresh water is continuously being added. It does not favor impounded water. (Figs. 74 and 75.)

Anopheles punctipennis (Say) (Fig. 73) is said to be the most widespread anopheline in North America. The wings have black and yellow scales, the latter forming two spots on the costal margin, one of which is long and situated beyond the middle, the second smaller and near the apex, giving a mottled appearance to the wings. The proboscis is black and the palpi are unbanded. The general appearance of the body is dark brown. This species breeds in clear cool shaded pools. The females seldom enter dwellings but invade unscreened porches and bite in the open.

Anopheles pseudopunctipennis Theobald (Fig. 73) is a widespread species, according to Matheson, extending from Argentina along the coast

"It breeds almost wholly in still water that is relatively clean. It requires some sunshine, never being found in dense shade. However, it requires some darkness, never being found in waters which are wholly unshaded, unless they have a type of flotage which casts narrow strips of shade where the larvae may lie during a portion of the daylight hours. . . . An ideal breeding place for *A. quadrimaculatus* Say is in freshly impounded water which floods a basin containing underbrush and which is sparsely covered with trees. Such a body of water quickly gathers flotage of dead and dying land vegetation, twigs and leaves, among which algae soon appear. Such flotage not only offers the requisite amount of shade, but an abundant food supply. Such an impounding will not acquire a large quantity of natural enemies, such as top minnows and aquatic insects, for a number of years and seldom acquires enough entirely to prevent production of the mosquito.

"The normal detritus passing down a narrow stream will clog the interstices of a fallen tree or branch and create a dam. These natural impounded waters

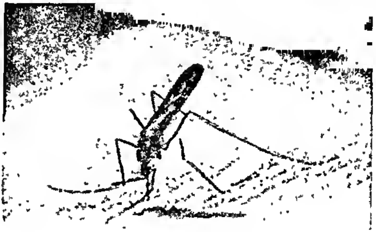

FIG. 72 —*Anopheles maculipennis* in the act of sucking blood from the author's hand

are excellent breeding places for *quadrimaculatus*. Swamps covered by a growth of virgin timber, on the other hand, are not good breeding places. Such swamps are almost invariably covered with such a dense timber growth that sunlight can reach the surface of the water only in those small areas where an opening has been made by the fall of a dead tree. Swamps of this description have a small seeding of *quadrimaculatus*, but not enough to propagate malaria. When the lumberman enters, cutting out the large trees, leaving the small ones, the branches and the tree tops, he changes a safe water surface into one almost ideal for *quadrimaculatus* production. He has let in the sunshine without removing all of the shade, and he has left behind waste which not only creates fine flotage, but large portions of which tend to clog the channel which traverses the average swamp, thus making a series of ponds."

The brood peaks of this species in southwestern Georgia according to Boyd[37] are from twenty to thirty days apart and there are from eight to

ten annual broods, the first appearing from twenty to thirty days after the last frost, and the last brood, the tenth, if there is favorable weather in December. January and February he states are the only months when no broods emerge.

Anopheles maculipennis Meigen (Figs. 72 and 73) is a widespread species in Europe and occurs along the [illegible] States [illegible] species on the Pacific coast is [illegible] under the name *Anopheles occidentalis* D. and K. This species also has four spots on the wings, resembling *A. quadrimaculatus* Say so closely that an examination of the [illegible]

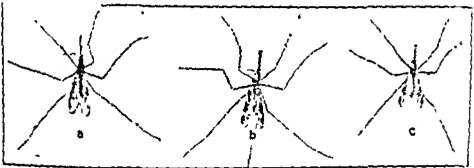

FIG. 73—Californian Anopheles: (a) *A. maculipennis*, (b) *A. punctipennis*; and (c) *A. pseudopunctipennis*

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and *A. quadrimaculatus* Say, totaling 1,377 specimens, compares the numbers of each species taken inside dwellings, under dwellings, privies, vacated buildings, cattle sheds, horse and mule sheds, fowl roosts and wagon and tool sheds. In commenting on his results he states:

> "It is indicated that in the three sources of direct human influence, namely, inside dwellings, under dwellings, and in privies, tbe last produced the greatest number of specimens of *A. punctipennis*. This species comprised less than one-third (30 per cent) of tbe catch in bouses, while under dwellings 62 per cent of the mosquitoes collected proved to be *A. punctipennis*. . . . It has been observed by s[illegible]
> *tipennis* rarel[illegible]
> on tbe porch [illegible]
> sumably und[illegible]
> "that *Anopheles* (*Pyretophorus*) *costalis*, a malaria carrier incriminated experimentally in Mauritius, prefers verandas to inner rooms and also bites in the open."

During the summer of 1920, from May 12 to July 13, daily collections of mosquitoes were made by the writer and his associates at Vina (Northern Sacramento Valley, California), one series being indoors and the other outdoors. The indoor collections were made regularly in the same buildings consisting of a cowshed, a washhouse, showerbath, storehouse and dwelling, while the outdoor collections were made under a short wooden bridge within ten to twelve fect of an aggregation of shacks occupied by Chinese and negroes. The indoor series taken in an area where control measures were in progress does not represent a large number of mosquitoes but the fact remains that of 77 anophelines taken, 50 were *Anopheles maculipennis* Meig. (including only one male) and 27 were *A. punctipennis* (Say) (including two males), or practically twice as many of the former. On the other hand, the outdoor series represented a total of 343 anophelines of which 102 were *A. maculipennis* Meig. (42 males and 60 females) and 241 were *A. punctipennis* (Say) (130 males and 111 females) or something over twice as many as the latter.

These collections bear out very well the general observations that *A. maculipennis* Meig. like *A. quadrimaculatus* Say is typically an invader of houses and consequently of greater importance as a malaria carrier, while *A. punctipennis* (Say) is chiefly an outdoor biter, porch biter, etc., and consequently probably of less importance as a malaria carrier. During the entire period of two months the well-screened cottage which was occupied by our party was not invaded a single time by *A. punctipennis* (Say), wbile *A. maculipennis* Meig. was a common visitor. *Anopheles pseudopunctipennis* Theob. is considered a field mosquito and in California is apparently of no consequence. As already stated it is a vector of malaria in Argentina, Central America and Mexico where it invades houses.

Key to Culicid Tribes and Genera of the United States

(Prepared by T. H. G. Aitken after various authors)

1. Abdomen without scales, or at least with the sternites largely bare. Scutellum never trilobed, crescent-shaped with the marginal setae evenly distributed. Palpi (males and females) as long or almost as long as the proboscis. Tribe Anophelini, Genus *Anopheles* Meigen 1818
   Abdomen with both tergites and sternites completely clothed with scales. Scutellum trilobed (except Megarhinini—spurious vein extends toward base of wing in upper basal cell from angle of R_{4+5}). Palpi (females) much shorter than the proboscis.... 2

2. Proboscis rigid, outer half more slender and bent backwards
   Tribe Megarhinini, Genus *Megarhinus* Robineau-Desvoidy 1827
   Proboscis more flexible, of uniform thickness (unless swollen at tip), outer half not bent backwards.... ....Tribe Culicini 3

3. Postnotum with setae..............Genus *Wyeomyia* Theobald 1901
   Postnotum without setae 4

4. Wing membrane without microtrichia. Cell R_2 shorter than its stem; anal

   Wing
   Anal vein extending well beyond fork of cubitus 5

5. Post-spiracular bristles present......... 6
   Post-spiracular bristles absent 8

6. Pre-spiracular bristles present (even if few)
   Genus *Psorophora* Robineau-Desvoidy 1827
   Pre-spiracular bristles absent 7

7. Wing scales mostly narrow, or when broad, setae are present on upper side of base of R_1 (1st vein)..............Genus *Aedes* Meigen 1818
   Wing scales broad; setae absent on upper side of R_1
   Genus *Mansonia* Blanchard 1901 (Subgenera *Mansonia*, *Mansonioides*, *Rhynchotaenia*)

8. Pre-spiracular bristles present; lower side of base of R_1 (1st vein) distinctly pilose ....Genus *Theobaldia* Neveu-Lemaire 1902
   Pre-spiracular bristles absent; lower side of base of R_1 scaly or bare .. 9

9. Pulvilli present 10
   Pulvilli absent 11

10. Second joint of antenna (first flagellar) very long in both sexes, antenna of male not plumose........Genus *Deinocerites* Theobald 1901
    Second joint of antenna normal; antenna of male nearly always plumose
    Genus *Culex* Linnaeus 1758

11. Fourth joint of front tarsus very short (both sexes); first segment of front tarsi longer than the last four together
    Genus *Orthopodomyia* Theobald 1904
    Fourth joint of front tarsus not shortened in female; first segment of front tarsi not longer than last four together
    Genus *Mansonia* Blanchard 1901 (Subgenus *Coquillettidia*)

Key to the Anopheline Mosquitoes of the United States

(Prepared by T. H. G. Aitken after various authors)

ADULTS

1. Tarsi, especially the hind pair, marked with white; wings usually with four or more pale costal areas
   Anopheles (Nyssorhynchus) albimanus Wiedemann 1821
   (Florida, Key West; Greater Antilles; Texas, Rio Grande Valley; Mexico; Central America; Panama; Ecuador; Venezuela; ground pools and brackish water)

   Tarsi dark, rarely a little white at base of first hind tarsus; wings rarely with more than two pale spots on costa.......................... 2
2. Wings with white or yellowish-white areas along the costal margin.... 3
   Wings without such markings.................................. 5
3. Wings with only one pale area on costal margin, located at apex; anal (6th) vein with three black spots
   Anopheles (Anopheles) crucians Wiedemann 1828
   (Coastal region of eastern U. S, New York to Florida, Cuba, Gulf States, Mexico-Tampico; ground pools, preferably with some salt admixture)

   Wings with at least two distinct costal pale areas; anal (6th) vein not as above 4
4. Vein R_{4+5} (3rd) largely pale-scaled, darker on basal third and near apex; palpi banded.. . ...*A (A.) pseudopunctipennis* Theobald 1901
   (California, Oregon, Arizona, Tennessee-Memphis, southern Texas, Mexico, Central America, east coast of South America to Argentina; semi-permanent ground pools, receding creeks.)

   Vein R_{4+5} dark; palpi unbanded.....*A. (A.) punctipennis* (Say) 1823
   (Southern Canada, U S, Mexican plateau, Venezuela; nearly all aquatic situations except leafy pools in deep woods; somewhat associated with shade in California.)
5. Wings with distinct black spots.......... 6
   Wings without distinct black spots 7
6. Bronze or coppery spot on wing apex (California coastal form) (male terminalia characters better).......*A. (A) maculipennis* Meigen 1818
   (Europe, Asia, Mexico, western U. S, British Columbia, Yukon, eastward through Canada, Massachusetts; fresh water ground pools, rice fields)

   Wing apex uniformly black. ......*A (A) quadrimaculatus* Say 1824
   (From Mexico north through Mississippi Valley to Canada and eastern seaboard; permanent ground pools and impounded water.)
7. Small species with rounded thorax; palpi not pale-ringed
   A (A.) barberi Coquillett 1903
   (Eastern U S., New York southward; tree holes.)

   Moderate-sized species, normal; palpi faintly pale-ringed
   A. (A.) atropos Dyar & Knab 1906
   (Gulf coast of U. S. Florida, Mississippi, Louisiana; brackish pools), and *A. (A.) walkeri* Theobald 1901 (sparingly through eastern N. America west to Minnesota; permanent or semipermanent water containing much vegetation.)

MALES

1. One spine on parabasal lobe; two accessory spines on prominence almost halfway between base and apex of basistyle
Anopheles (Nyssorhynchus) albimanus Wiedemann 1821
Two spines on parabasal lobe; no accessory spines 2
2. Phallosome without leaflets..*Anopheles (Anopheles) barberi* Coq 1903
Phallosome with leaflets.. 3
3. Leaflets of phallosome serrate, two pairs
A. (A.) pseudopunctipennis Theo. 1901
Leaflets of phallosome not serrate; more than two pairs.... 4
4. Claspette not bilobed, triangular in outline; basistyle with scales
A. (A.) crucians Wiedemann 1828
Claspette bilobed; basistyle without scales..... 5
5 Spines of dorsal lobe of claspette spatulate........... 6
Spines slender, spine-shape 8
6. Inner (ventral) spine of ventral lobe of claspette longer and stouter than outer (dorsal) one; diststyle without patch of minute, non-papillated hairs at base ....*A (A) quadrimaculatus* Say 1824
Outer (dorsal) spine longer and stronger than inner one; diststyle with patch of minute, non-papillated hairs at base................ 7
7 Basal (3rd) pair of leaflets small and slender, about one-fifth as long as first pair ....*A (A) atropos* Dyar & Knab 1906
Basal (third) pair of leaflets smallest, one-half the length of first pair
A. (A.) walkeri Theobald 1901
8. Dorsal lobe of claspette with two or three sharply pointed spines; lobe of ninth tergite very long and bluntly rounded at apex
A. (A) maculipennis Meigen 1818
Dorsal lobe of claspette with two sharply pointed spines; lobe of ninth tergite short, curving upward; hairy patch of minute, non-papillated hairs at base of diststyle not so extensive as in above
A (A) punctipennis (Say) 1823

LARVAE

1 Elements of the dorsal float-hairs (palmate tufts) smooth-margined on abdominal segments two to seven, with sometimes a small tuft on segment one....*Anopheles (Nyssorhynchus) albimanus* Wiedemann 1821
Elements of dorsal float-hairs notched toward tip; tufts never present on abdominal segment one 2
2 Abdomen with plumose lateral hairs on first six segments; head with small simple hairs only.....*Anopheles (Anopheles) barberi* Coq 1903
Abdomen with plumose lateral hairs on first three segments only; head with plumose hairs 3
3 Both inner and outer clypeal hairs simple, not branched
A. (A.) pseudopunctipennis Theobald 1901
Outer clypeal hair branched, fan-like; inner hair simple.............. 4
4. Abdomen with six pairs of dorsal float-hairs.. 5
Abdomen with five pairs of dorsal float-hairs...................... 6
5. Mandible with eleven terminal teeth; six branched hairs on mandible, arranged in an outward projecting row
A. (A) quadrimaculatus Say 1824

Mandibles with nine terminal teeth; ten branched hairs on mandible, arranged in a forward projecting row. . . *A. (A.) walkeri* Theobald 1901
6. Lateral plate of eighth abdominal segment with 17-22 teeth (six or seven of which are longer than the rest). . . . *A. (A.) punctipennis* (Say) 1823
Lateral plate of eighth abdominal segment with 22-29 teeth (eight or nine of which are longer than the rest). . . . *A. (A.) maculipennis* Meigen 1818

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CHAPTER XII

MOSQUITOES AS VECTORS OF DISEASE

A. Malaria

Malaria.—Malaria is a widely distributed disease, prevalent to a greater or less degree on every continent and on many islands of the seas. It is considered to be the most important disease of man. In the United States alone where malaria is on a rapid decline there were an estimated 900,000 cases in 1935 [1] and approximatdly 3,900 deaths were reported for 1934 in 13 southern states [2] Its presence is dependent upon a complex of environmental factors favorable to the development of large numbers of malaria-bearing mosquitoes as well as to the parasites causing the disease. Temperature, particularly as it affects the development of the plasmodium in the mosquito, and humidity as it affects the life of the latter, are important factors; a mean summer isotherm of 15° to 16° C. in general limits its geographical distribution fairly well. The distribution of malaria is also dependent to a large degree upon rainfall; however, naturally arid regions may be seriously affected by imperfections in irrigation if this is practiced. Although lowlands are more likely to be affected, this does not hold as a general rule, because one or more important factors may be lacking so as to render lowlards quite immune; also the disease may occur at high elevations (9,000 feet in Quito) under favorable circumstances; the writer found endemic malaria in California at an elevation of about 5,500 feet.

Few diseases have so large a list of synonyms; among these are ague, chills and fever, jungle fever, paludism, marsh fever, remittent fever, intermittent fever, *Wechselfieber*, *Kaltesfieber*, etc. The symptoms, even though slight, are usually manifested as a more or less regularly appearing paroxysm consisting of three fairly well-defined stages, viz.: the *cold stage* (the chill) in which the skin becomes pale and has the appearance of "gooseflesh," the patient's teeth may chatter, and he may shiver more or less violently; the next stage is the *hot stage*, or fever, the temperature rising during the chill, the skin is hot and flushed; the third stage is marked by the appearance of a general perspiration, the fever falls, and the temperature approaches normal. The entire paroxysm may last but a few hours. In many cases the stages are not well marked, neither do the paroxysms recur at exactly the same interval. The interval depends largely on the type of infection. When the paroxysm occurs

at intervals of 24 hours, as is often true in the early stages of infection or in multiple infections, it is *quotidian*; when the interval is 48 hours or every third day it is *tertian;* and when the interval is 72 hours or every fourth day, it is *quartan.*

The disease is caused by infection with one or more of several species of blood-inhabiting protozoa belonging to the genus *Plasmodium.* Boyd,[3] whose "Introduction to Malariology" should be read by all students interested in malaria, wisely points out that under the clinical term "malaria," we are in reality confusing three diseases, which while produced by similar parasites and having similar means of transmission, possess certain individual characteristics. These parasites attack the red blood corpuscles, destroying them while reproducing asexually; this asexual reproduction or sporulation occurs at more or less regular intervals, i.e., 48 or 72 hours, depending upon the species of *Plasmodium.* The infection, according to Reed,[4] results in (1) changes in organs, such as enlargement of the spleen and liver, heart involvements, "capillaries in the brain and pia in fatal subtertian cases are found congested or blocked by schizonts and sporulating forms of plasmodia, with punctiform hemorrhages in the white matter of the cerebral cortex"; (2) leucopenia with increase of mononuclears and varying degrees of anaemia as the result of direct destruction of red cells by plasmodia and indirect degeneration of others; (3) malarial pigment (melanin) in macrophages in the splenic sinuses is characteristic as are also the heavy pigment deposits in the cells in the splenic vein and liver (Reed); it is the same pigment as that produced in the red cells by the plasmodia and released with the rupture of infected red cells; (4) changes in physiology such as periodic febrile paroxysms which are quite regular in benign tertian malaria but because of irregular maturing of plasmodia the periodicity of the paroxysms is often concealed in subtertian malaria; focal symptomatology due to localization in subtertian [*Plasmodium falciparum* (Welch)] arising from the "sticky tendency" of parasitized red cells which causes agglutination and blockage; (5) malaria cachexia, a chronic condition following repeated malarial attacks; (6) immunity in children; however, this is often lacking—it is perhaps racial, or it may be dependent upon the frequency of infections. True antibodies have not been demonstrated.

Historical.—Malaria, while not receiving its name until the middle of the eighteenth century, has been known for many centuries, Hippocrates having divided periodic fevers into quotidian (daily), tertian (every third day) and quartan (every fourth day). The fable of Hercules and the Hydra is believed to refer to malaria. The successful treatment of malaria dates back to before the seventeenth century. The Countess de Chinchón, the wife of the Viceroy of Peru, is said to have been cured of fever in 1638 by the use of the bark from a certain tree. This bark

was introduced into Europe in 1640 and in 1741 Linné named it "cinchona" in honor of the Countess. In 1753 Torti named the disease "malaria," believing it to be air-borne and emanating from the bad air (*mal aria*) rising from swamps and marshes. Credit for the discovery of the causal agent in 1880 belongs to C. L. A. Laveran, a French army surgeon who was then stationed in Algeria. Although the mosquito transmission theory is said to have been held for many years among the Italian and Tyrolese peasants and the natives of what was formerly German East Africa, the first well-formulated mosquito-malaria theory was advanced by Dr. A. F. A. King in 1883 [5] In 1885 and 1886 Golgi [6] discovered that the course of the fevers corresponded to the development of the parasites in the blood corpuscles and particularly to their periodic sporulation. He demonstrated this for both the quartan and tertian parasites.

Manson expressed a strong belief in the malaria-mosquito theory as early as 1884, and it was his sustained guidance and encouragement that carried the late Sir Ronald Ross [7] on to those brilliant discoveries in India in 1897 that definitely incriminated mosquitoes as vectors of malaria, and twice won for him the Nobel prize. Although Ross made important discoveries with human malaria and anopheline mosquitoes, his chief discovery was the life history of the parasite of bird malaria in a culicine mosquito.

Great credit is due MacCallum [8] for his discovery in 1897 that the flagellated bodies which Ross had found in the intestines of mosquitoes were actually male parasites and that these fertilize the female cells, thus giving the clue to the nature of the pigmented cells in the stomach wall of the mosquitoes. MacCallum actually observed the process of fertilization in blood taken from a patient suffering from aestivo-autumnal malaria. After describing the process of flagellation in the bird infection and entrance of the "flagellum" into the granular round form, MacCallum remarks (p. 126), "Have we not here, without much doubt, a sexual process in the organisms the result of which is the motile vermiculus. . . . We can thus consider the two forms of adult organism found in the fresh blood as male and female, the granular form containing more chromatophilic substance than the hyaline male form, which we may now say gives up its life in the production of four or more spermatozoa or flagella."

In an addendum MacCallum (loc. cit.) states that he had

"examined the blood of a woman suffering from an infection with the aestivo-autumnal type of organism, in which a great number of crescents were to be seen. These in a freshly made slide of blood, with very few exceptions, retained their crescentic shape for only a few minutes. They soon drew themselves up, thus straightening out the curve of the crescent while shortening themselves into the well-known ovoid form. After the lapse of 10 to 12 minutes most of them were quite round and extra-corpuscular, the 'bib' lying beside them as a delicate circle or 'shadow' of the red corpuscle.

"After 20 to 25 minutes certain ones of these spherical forms became flagellated; others, and especially those in which the pigment formed a definite ring and was not diffused throughout the organism, remained quiet and did not become flagellated. In a field where an example of each f[illegible]

[illegible] ng around. The rest were refused admission, but swarmed about, beating their heads against the wall of the organism. This occurred after 35 to 45 minutes

"After the entrance of the flagellum the organism again became quiet and rather swollen, but although in the two instances in which this process was traced, the fertilized form was watched for a long time, no form analogous to the 'vermiculus' was seen."

During this same period of intensive discovery in the field of malaria Grassi [9] and associates proved that human malaria is transmitted by a particular genus of mosquito, namely, *Anopheles*.

In 1900 at the suggestion of Sir Patrick Manson, Sambon and Low built a mosquito-proof hut in the Roman Campagna, in which they lived during the most malarial months of that year without contracting malaria, taking precautions against mosquito bites by promptly retiring within doors at sunset, otherwise living as did the natives. At this time these investigators sent infected *Anopheles* mosquitoes from the Roman Campagna to London, where Dr. Manson's son, Dr. P. Thurburn Manson and Mr. George Warren permitted themselves to be bitten by these mosquitoes and "shortly afterwards both of these gentlemen, neither of whom had been abroad or otherwise exposed to malarial influences, developed characteristic malarial fever, and malarial parasites were found in abundance in their blood, both at that time and on the occurrence of the several relapses of malarial fever from which they subsequently suffered. The mosquito-malaria theory has now, therefore, passed from the region of conjecture to that of fact." [10]

Bass and Johns [11] in 1912 were the first to rear successfully the malaria parasite *in vitro*.

The plasmodia.—The causal organisms of malaria belong to the genus *Plasmodium* of the family Plasmodiidae, suborder Haemosporidiidea, order Coccidiida, class Sporozoa, Phylum Protozoa. They are blood-inhabiting parasites, passing their asexual cycle and developing gametocytes within the red blood corpuscles of the host where they produce a characteristic pigment.

If parasites are present in the blood they should be visible, after proper staining (Giemsa, Leishman, Wright's), on careful microscopic examination, as pigmented intracorpuscular bodies in the form of signet rings, ameboid organisms, or as crescents in aestivo-autumnal fever of 10 or more days' duration.

Ross[12] states that the parasites "will not generally be numerous enough to cause illness unless there is at least one parasite to 100,000 haematids; that is, 50 parasites in 1 c.mm. of blood; or 150,000,000 in a man 64 kilograms (142 pounds) in weight. . . . Such calculations demonstrate the absurdity of supposing that there are no plasmodia present in a person because we fail in finding one after a few minutes' search. As a matter of fact, even if as many as 150,000,000 plasmodia are present in an average man, the chances are that ten to fifteen minutes' search will be required for each plasmodium found; while if we are careless or unfortunate, we may have to look much longer."

a. Plasmodium falciparum (Welch 1897) (*Plasmodium praecox* Blanchard 1900) is the causative organism of *aestivo-autumnal* fever (subtertian) of the tropics and subtropics, which is the most severe form of malaria, often resulting fatally. Although it is a *tertian* fever there is considerable irregularity in the occurrence and duration of the febrile stage owing to a corresponding irregularity in the sporulation of the parasites, schizogony usually requiring about 48 hours, though often less. The infected red corpuscles are usually normal in size, though some may be slightly shrunken, often crenated and rather dark green (brassy). The intracorpuscular parasite in all its stages is small (not over two-thirds the size of a corpuscle) and fairly ovoid in outline; the pigment is darker than in other forms; clumps early in coarse granules, and "Maurer's dots" appear in the corpuscles in the later stages. The *signet ring* is thin and small and the chromatin dot is commonly double and out of line with the ring. There may be two and even four signet rings in one red corpuscle. The segmented state, rarely if ever seen in the peripheral blood, produces from eight to twenty-four *merozoites*. Characteristic crescent-shaped or kidney-shaped bodies appear in the peripheral blood in about 10 days after infection; these are the sexual forms (*gametocytes*) and occur in this species of *Plasmodium* only. The *macrogametocyte* or female form, measuring from 10 to 15μ, shows the chromatin granules well concentrated in the mid-region, while the *microgametocyte* or male form, measuring from 7 to 10μ, has a more hyaline appearance. A remnant of the red blood corpuscle often remains slung from the opposite ends of the crescent and forms the so-called "bib."

b. Plasmodium vivax (Grassi and Feletti 1890) is the cause of tertian fever of temperate climates, which occurs also abundantly in the tropics and subtropics, with regularly recurrent paroxysms every 48 hours. The parasitized corpuscles are distinctly enlarged, quite pale, and contain fine pigment granules known as "Schüffner's dots." The signet ring is large and conspicuous and the dot is in line with the ring and rarely double. The fully grown *merocytes* or *schizonts* are very irregular and bizarre in form. The number of elements, *merozoites*, in the sporulating

or segmented stage commonly seen in the peripheral blood is from 12 to 24 (usually about 16) and their arrangement is irregular. *Sporulation* occurs regularly every 48 hours. There are no "crescents" in this species; the gametocytes are round or oval in form, filling practically the entire red cell when full grown. The *macrogametocyte* has the chromatin arranged in a compact mass; the *microgametocyte* has the pigment well distributed and presents a more hyaline appearance.

c. Plasmodium malariae (Laveran 1881) is the cause of quartan fever, with recurrent paroxysms every 72 hours. This form of malaria is much less common but coincides in distribution with aestivo-autumnal fever. The pigment is coarse and generally occurs in marginal streaks. The parasitized corpuscles are usually normal in size, and the parasite is small and more or less oval in shape though when partly grown it frequently extends across the equator of the corpuscle in the form of a band. The ring-forms have one vacuole and usually one dot. The gametocytes are rarely seen. The segmenting stage gives rise to the typical "daisy" form, each sporulated body radiating from the center. The number of bodies varies from 6 to 12, usually eight. Sporulation occurs every 72 hours. The gametocytes resemble those of *Plasmodium vivax*.

d. Plasmodium ovale Stephens 1922 is the cause of a mild form of tertian fever in Africa. The name is due to the oval shape which is generally assumed by the parasite as well as the infected corpuscles. The infected corpuscles do not become enlarged. The pigment is dark and granular and "Schüffner's dots" are present in all stages. The merozoites range from 8 to 12 in number.

Life history of the Plasmodium.—The life history of the malaria *Plasmodium* involves two distinct cycles; first, the *asexual*, also known as the human cycle, cycle of Golgi,[13] or schizogonic cycle; and, secondly, the *sexual*, also known as the mosquito cycle, cycle of Ross or sporogonic cycle.

The *asexual* cycle (Fig. 76), accomplished in the blood of man, begins with the introduction of spindle-shaped *sporozoites* injected into the circulation with the bite of the anopheline mosquito. Each sporozoite not destroyed by leucocytes at once enters a red cell, where it (now known as a *trophozoite*) quickly goes into the *signet ring* stage, growing rapidly until the corpuscle is more or less filled depending upon the species of parasite, and it is then known as a *merocyte*. The full-grown merocyte (also known as a *schizont*) now divides into a larger or smaller number of bodies (also depending upon the species) which are then liberated, and when free in the plasma are known as *merozoites*. The time required for this sporulation is from 24 to 72 hours according to the species. Each merozoite unless destroyed by leucocytes now attaches itself to and gradually enters another red cell and again the cycle repeats itself until the

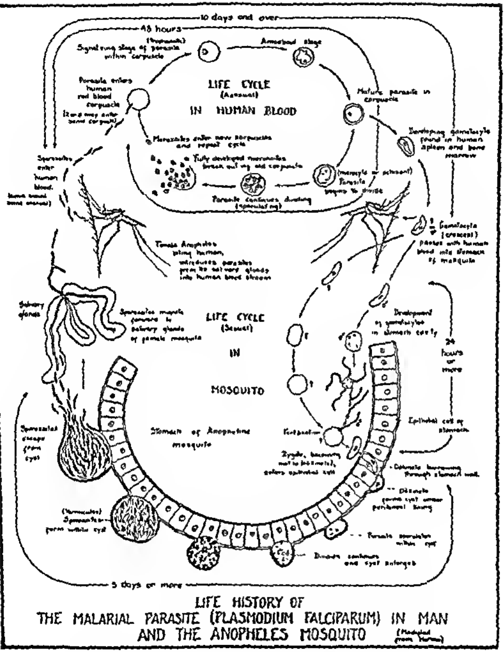

FIG 70 —The life cycle of *Plasmodium falciparum*

infection is great enough to produce a paroxysm, i.e., in from 6 to 12 days, commonly about 10 days. The paroxysms are due to the sudden liberation of end products.

The great majority of the merozoites are asexual, but some of them are potentinl males and females, which require a longer time, *probably* not less than 10 days, to develop to their full growth, and are then known as *gametocytes*. In *Plasmodium vivax* the sexual forms are not easily recognized; however, the following characters are useful: "(1) their larger size, (2) more abundant pigment, (3) there is usually oaly one fairly large chromatin mass, whereas in nn asexual form (*schizont*) of nearly equal size the chromatin has already begun to divide into several portions (segmenting stage)" (Stephens and Christophers). Ia *P. falciparum* the sexual individuals are in the form of *crescents*. The female crescent (*macrogametocyte*) has the pigment collected at the center, while the male crescent (*microgametocyte*) has the pigmeat scattered throughout and is known as n hyaline crescent.

With complete development of the gametocytes all is ready for the next cycle (the sexual) which can only be completed within the body of certain species of anopheline mosquitoes. In the meantime the asexual cycle is repeated until senescence of the parasite occurs or unless quinine or another plasmodiacide is taken to destroy them. The gametocytes are not easily destroyed, persisting in the body for long periods of time, during which time the infected person is a carrier. A person eveatually removed from reinfection becomes rid of malaria because of the seaescence which naturally results from continued sporulation without sexual intervention or rejuvenation ia the mosquito. It is believed that this senesceace or eventual dying off of the nonsexual forms is due to the toxin produced by the organisms reacting upon themselves.

The sexual cycle is necessary to the life of the species. It is a well-known fact that the male gametocyte extrudes flagella whea malarial blood is exposed to the air, as when in coatact with a glass slide. The parasites when thus taken from their normal habitat iavariably die withia a few minutes, unless a special medium is employed; e g., that devised by Bass aad Johns (loc. cit.) ia which the asexual cycle may be observed outside of the human body.

Sexual development, the cycle of Ross (Fig. 76), has oaly beea observed in certain female anopheline mosquitoes; in the stomach of which flagellatioa of the male gametocyte takes place. After a peripheral arraagement of the chromatin (in clumps correspondiag to the aumber of flagella) there are extruded from three to six long slender filaments (flagella), each of which breaks loose from the pareat body (exflagellation), forming the male *gamete* (*microgamete*) correspoading in fuaction to the spermatozoön of higher animals. The female gametocyte,

FIG 77.—Shows stomach of female anopheles mosquito with numerous plasmodial cysts (Photo by Mayne)

now known as the *macrogamete,* having been taken into the stomach of the mosquito with the microgametocytes in the act of sucking blood, also undergoes certain changes (maturation), becoming rounded or oval in form with the chromatin mass centrally located. In this condition and still in the stomach of the mosquito, the microgamete conjugates with the macrogamete, producing the *zygote,* which soon becomes motile and is then known as the *oökinete* or vermiculus, in which stage the epithelium of the stomach is penetrated and a position is shortly taken up just beneath the peritoneal membrane. Based on his studies of the plasmodia of birds Huff [14] points out that this penetration of the stomach wall

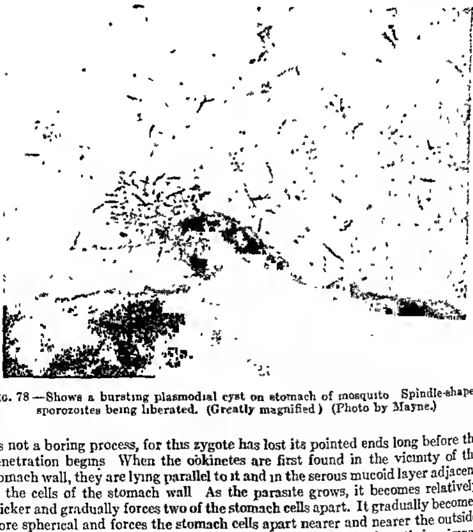

FIG. 78 —Shows a bursting plasmodial cyst on stomach of mosquito Spindle-shaped sporozoites being liberated. (Greatly magnified) (Photo by Mayne.)

"is not a boring process, for this zygote has lost its pointed ends long before the penetration begins When the oökinetes are first found in the vicinity of the stomach wall, they are lying parallel to it and in the serous mucoid layer adjacent to the cells of the stomach wall As the parasite grows, it becomes relatively thicker and gradually forces two of the stomach cells apart. It gradually becomes more spherical and forces the stomach cells apart nearer and nearer the outside of the stomach wall The stomach cells now begin to come back to their original positions on the inner side. Finally the parasite, now an oöcyst. comes to lie under the outer envelope of the stomach."

In this position the parasite grows enormously, forming an *oöcyst* (Fig. 77) in which many nuclei appear in from four to five days. These tiny

nucleated bodies give rise to hundreds of spindle-shaped organisms (*sporozoites*) which are shed into the body cavity of the mosquito in from 24 to 48 hours (Fig. 78). The majority of the sporozoites eventually collect in the salivary glands, remaining there until the mosquito bites again, when many of them may be injected with the saliva into the wound. The time required for the completion of the sexual cycle varies from 7 to 10 days under favorable conditions. Once infected the mosquito probably remains infected and infective for the rest of its life.

Anopheles infectivity experiments.—Contrary to a widespread belief, not all anophelines are able to transmit malaria. Hindle [15] points out that, "the first instance of an *Anopheles* being shown not to transmit malaria was in the case of the common Indian species *Anopheles subpictus* (rossi) Grassi. This species is found quite commonly in very large numbers associated with every degree of prevalence of malaria, but it has not been shown to act as a transmitting agent (in India) under natural conditions, though it can be infected experimentally." The writer has seen enormous numbers of *A. pseudopunctipennis* Theobald in certain parts of California under presumably favorable climatic and population conditions and yet malaria was practically absent while in other near-by localities, where in addition to the above either *A. punctipennis* (Say) or *A. maculipennis* Meig., or both, were present even in comparatively small numbers, endemic malaria occurred. Furthermore, the several species of *Anopheles* do not all equally favor the *several* species of malaria plasmodia, thus *A. maculipennis* Meig and *A. quadrimaculatus* Say are known to be carriers of all species of plasmodia (Beyer, et al.,[16] Thayer,[17] King [18]) while *A. punctipennis* (Say) is a strong carrier of the tertian parasite and a very weak one (probably negligible) for the aestivo-autumnal parasite (Darling [19]). Anophelism without malaria is discussed in the previous chapter.

The following experiment made by Mayne (Mitzmain [20]) illustrates a procedure in infectivity experiments:

"For the purpose of this study, 338 specimens of *Anopheles punctipennis* were collected in barns and stables at Talladega Springs, Ala., January 7–15, 1916, and transported in cages to the New Orleans laboratory (The improbability of infection of 'wild' Anopheles mosquitoes in this section and during this season seemed to warrant their use in conducting these experiments.) The feeble and dead mosquitoes were withdrawn upon arrival and either used for smear preparations or dissected in the usual manner for the purpose of examination for malarial parasites. One hundred and sixty-six mosquitoes were separately suspended in a drop of saline dissecting medium on a slide and the abdominal and thoracic contents were teased out. Smears were then made from each and stained over night in a weak Giemsa stain.

"One hundred and twenty-six specimens were fed on a healthy person at least once each, then dissected during a period of 20 days. The results in all instances failed to indicate the presence of any plasmodial infection.

"An untreated patient suffering from tertian malarial fever volunteered fo[illegible]

[illegible] termination of which period (February 6 and 7) mosquitoes were applied to the patient.

"The paucity of sexual parasites in the blood of the donor may be appreciated from the counts made in a thick film and a thin film prepared February 7. In the two preparations 1,231 leucocytes were counted and the matured gametocytes encountered numbered two, an average of one gametocyte to 616 leucocytes. In addition to these there were observed in the two blood specimens 48 half-grown gametocytes and 5 ranging in size from three-fourths to nearly full-grown forms. At the time of these examinations the patient had been started on a course of quinine treatment.

"Forty specimens of *Anopheles punctipennis* were applied to the tertian donor in two lots on February 6 and 7, 1916; 20 of these died within five days and were dissected. Oökinetes were observed in at least eight of these, from which smear preparations were made. Twenty mosquitoes were dissected during a developmental period ranging from 6 to 25 days.

"During the course of the experiment raisins and water were furnished as food, while the mosquitoes were subjected, prior to the 10th day, to an incubator temperature of 25.5°–26° C. Thirteen of this lot of 30 (equal to 32.5 per cent) became infected.

"In order to eliminate any possibility of doubt as to the nature of the parasites harbored by the mosquitoes and as a further check on the infectivity of *Anopheles punctipennis*, three healthy persons volunteered to permit biting of these mosquitoes. Four specimens were selected for the purpose, namely, Nos 18, 23, 24 and 25. The first volunteer (H. E. H.) was bitten February 17 by all four of the mosquitoes applied. At this time the mosquitoes had been infected 10 days. In this feeding, the mosquitoes were not permitted to engorge themselves but were applied a sufficient length of time to convince the observer and the host that blood was being withdrawn. Directly after the biting, six very distinct moderate-sized macules developed on the arm at the site of application. Nine days elapsed before the volunteer experienced prodromal symptoms of any kind. The first paroxysm was observed 14 days after the biting and parasites of *Plasmodium vivax* were found in the blood of H. E. H. on March 3 and March 4.

"H. E. H. was employed previously in feeding mosquitoes which had been given the opportunity of becoming infected in two experiments from subtertian crescent carriers. More than 200 specimens of *Anopheles punctipennis* had been used in an attempt to transmit subtertian infection, with negative results. The volunteer, H. E. H., remained healthy throughout this test and subsequently for four months prior to the tertian transmission experiment. In the tertian infection the disease took its usual course and prompt recovery followed the use of therapeutic doses of quinine.

"Two of the mosquitoes, namely, Nos 23 and 24, were induced to bite the second volunteer, Dr. H. A. T., February 18. These were observed to bite vigorously to a point of repletion. The mosquitoes at this time had been infected for a period of 11 days. After an incubation period of 14 days, Dr. H. A. T.

experienced a distinct paroxysm; also on the same day parasites of tertian malaria (*Plasmodium vivax*) were found in his blood.

"A third volunteer, Dr. R. C. D., was bitten February 21 by mosquitoes Nos. 24 and 25, 14 days after they had received an opportunity to become infected. The two specimens were applied to the arm so that they did not become engorged (interrupted feeding); the labia of both were observed to be inserted to the extreme before the mouths were withdrawn Each bite required 40 seconds of time, resulting in distinct macules at the point of inoculation.

"An incubation period of 14 days followed in this case, with prodromata and the usual symptoms of chill followed by fever A slight paroxysm was experienced on March 4, and parasites were observed March 5 Distinct tertian rings (*P. vivax*) were demonstrated in the blood of the volunteer in two specimens examined at five-hour intervals on the second day after onset."

Number of persons infected by one mosquito.—It is important to know whether an *Anopheles* once infected can infect more than one person without again feeding on infective blood. For example, country-school privies as the writer has often observed may be infested with *Anopheles* mosquitoes and the opportunity is given many of them to bite different persons in quick succession. In a most instructive series of experiments conducted by Mayne (Mitzmain [21]) he reports that one mosquito proved to be the sole infecting agent in three cases. Mitzmain used *Anopheles punctipennis* (Say) with *Plasmodium vivax*. He also demonstrated in eleven experiments that short exposure to bites was sufficient to cause successful transmission of the disease.

Effect of temperature on parasites.—In spite of the fact that all conditions are apparently favorable—numerous anopheline carriers together with ample human population with sufficient carriers of plasmodial gametocytes—yet active malaria may be largely or wholly absent in particular localities. (See previous chapter.) An analysis of conditions will usually reveal the fact that the average temperature is low due to normally cool nights although the days may be fairly warm, or because of prevalent cool fogs. It is generally pointed out that malaria gametocytes cannot develop successfully within the body of the mosquito host below a temperature of about 60° F It is nevertheless a matter of interest to know that King [22] observed the survival of the parasite of tertian malaria in the mosquito host (*Anopheles quadrimaculatus* Say) at a temperature of 30° F. for a period of two days, at 31° F for four days, and at 46° F. for 17 days, and the parasite of aestivo-autumnal malaria survived a temperature of 35° F. for 24 hours.

In addition to the retardation and eventual complete inhibition of plasmodial development, temperature also plays an important rôle in the biology of anophelines, although the insect is able to endure much lower temperatures and is able to go into hibernation in cold climates.

Hibernating anophelines not carriers.—Hibernation of the anopheline host presents the problem of the overwintering of the parasite. Mayne (Mitzmain [23]) again comes forward with an excellent discussion of the question, "Is mosquito or man the winter carrier of malaria organisms?" He reaches the conclusions that

"hibernating Anopheles, collected in the region investigated (northwestern Mississippi), did not harbor parasites of malaria. This was determined after an examination of 2,122 dissected anophelines, of which 1,211 specimens were examined before May 15, 1915. Among the remaining 911 specimens, serving as a malaria indicator for the spring season, 3 mosquitoes, between May 15 and May 26, were definitely shown to contain oöcysts, indistinguishable from those seen in mosquitoes experimentally infected with human malaria.

"In the investigation of man as the responsible winter carrier, 1,184 persons, residing on the plantations selected, were examined for malaria parasites. Four hundred and ninety-two infections were identified microscopically; 317 cases were of the subtertian type, 8 were mixed infections, and the remainder were of the simple tertian type, with the exception of one quartan case.

"In the consideration of these infections an important fact stands out: *nearly one-fourth (24.8 per cent) of the human carriers harbored gametocytes*

"It was proved that from a group of 103 persons, examined in March, 1915, *8 of the 15 gametocyte carriers identified were similarly infected* during the preceding fall.

"The incrimination of man as the sole winter carrier is emphasized by the fact that 3 malaria-infected *Anopheles quadrimaculatus* were found in the homes of these gametocyte carriers during May 15 to May 26, previous to which time 1,180 specimens of *Anopheles* from this source were found to be negative."

Anophelines overwintering in warm stables and homes as explained in the previous chapter under races of *Anopheles maculipennis* Meig. may nevertheless play an important though highly circumscribed rôle in the transmission of malaria.

Anopheline vectors of malaria.—Covell,[24] who has critically reviewed the recorded data regarding the transmission of malaria by various species of *Anopheles* mosquitoes, points out that many species are possible vectors under certain conditions, yet the principal rôle is played by comparatively few. It is interesting to note that Covell calls attention to the fact that the bare record of dissections without knowledge of conditions such as human or animal habitations, season, etc., is of but little value, as is the finding of scanty gut infections. Also the fact that a species may be infected under laboratory conditions does not prove it is of sanitary importance. Knowledge of the preference of a species for human blood is valuable. The discovery of sporozoites under natural conditions is of the greatest importance. Examination of the gut only without the salivary glands is regarded as illogical. It is pointed out that "gland examination besides disclosing the most valuable evidence as regards

transmission and longevity has the great advantage that the specimen may be very easily and rapidly made into a permanent preparation by merely making a smear and staining it with Giesma's stain . . . (also) the results of dissecting . . . may be confirmed later if desired."

It is interesting to know that of the nearly 170 species of *Anopheles* only the following 26 are considered to be important vectors of malaria Covell lists the chief malaria-carrying anophelines of the world as follows:

United States, *Anopheles quadrimaculatus* Say and *A. maculipennis* Meig. (Pacific coast); Mexico, *A. albimanus* Wied, *A. pseudopunctipennis* Theo., *A. quadrimaculatus* Say; Central America, *A. albimanus* Wied., *A. tarsimaculatus* Goeld., South America, *A. albimanus* Wied, *A. albitarsis* L. A., *A. pseudopunctipennis* Theo., *A. tarsimaculatus* Goeld; Europe, *A. maculipennis* Meig., *A. superpictus* Grassi, *A. elutus* Edwards; Africa, *A. maculipennis* Meig., *A. algeriensis* Theo., *A superpictus* Grassi, *A. gambiae* (*costalis*) Giles, *A. funestus* Giles, *A. moucheti* Evans, *A. nili* Theo.; Asia, *A. maculipennis* Meig., *A. elutus* Edwards, *A. sergenti* (Theo.), *A. gambiae* Giles, *A stephensi* Liston, *A culicifacies* Giles, *A. fluviatilis* James, *A. minimus* Theo., *A. maculatus* Theo., *A. ludlowi* Theo., *A. umbrosus* Theo.; East Indian Archipelago, *A. ludlowi* Theo., *A. maculatus* Theo, *A. aconitus* Dönitz, *A. umbrosus* Theo., *A. hyrcanus* (*sinensis*) (Pallas), *A. leucosphyrus* Dönitz; Australia, Melanesia and Polynesia, *A. punctulatus* Dönitz. Since the résumé made by Covell several other species of the genus have been shown to be important vectors; among these *A. philippinensis* Ludlow in Bengal and *A. superpictus* Grassi for the Northwest Frontier of India. (Christophers, Sinton and Covell, 1936.)

Malaria surveys —Although an inquiry into the facts about malaria in some particular area may be described as a survey, Christophers, Sinton and Covell (third edition revised by Sinton)[23] point out that "it is far from being merely routine or mechanical" These authors point out that the circumstances affecting malaria are so varied "with its triple-linked chain of man, the parasite, and the mosquito, as well as all the various factors influencing this chain, that in the present state of our knowledge a malaria survey is almost always a true piece of research work. Such a survey is intended to guide policy and action . . . but it does not always follow that something can be done." Boyd (loc. cit.) in his excellent chapter (iii) on "malaria surveys" points out that surveys should be made only during or just following the usual malaria season, since the anopheline problem must be studied simultaneously. Only experienced persons should be entrusted with this task.

A physician trained in malariology is perhaps best qualified to direct a malaria survey although a medical parasitologist or medical entomologist trained as a malariologist may be equally suitable. In either case a technical staff will be needed; the physician as director would no doubt need an experienced medical entomologist, and the parasitologist (or medical entomologist) as director would need a properly trained physician on his staff. The size of the staff will depend largely on the size of the area to be surveyed. The staff would usually include a laboratory technician, field entomologist (a culicidologist), a surveyor and mapper, and a clerk.

After establishing headquarters and laboratory and having previously made the acquaintance and gained the coöperation of civil authorities, particularly the health officer, the following data will be assembled according to the authority, abilities, and assignments of the staff (maps and various items of equipment will be needed, such as breeding jars, collecting apparatus, stains, etc.): (1) spleen census and parasite index from blood films; (2) percentage prevalence of different species of plasmodia, also prevalence of gametocytes; (3) malaria—morbidity and mortality—statistics; (4) age incidence; (5) seasonal distribution; (6) occupation and economic status of malarial population, housing, etc.; (7) larval survey to ascertain kinds of anopheline breeding places; (8) numerical prevalence of different species of adult *Anopheles*, habitat preferences, such as houses, privies, pig pens, cattle sheds, etc.; (9) sporozoite rate based on salivary gland dissection; (10) oöcyst rate based on oöcysts on the wall of the mid-gut (careful note must be made as to origin of mosquitoes dissected, whether from human habitations, hog pens, privies, porches, stables, etc.); (11) meteorological conditions, rainfall, humidity, temperature, winds, etc.; (12) topography, soil, vegetation; (13) agricultural crops, methods of farming, irrigation, drainage, rice culture, etc.

Quinine prophylaxis and treatment.*—It has already been suggested in this and the preceding chapter that quinine holds an important place in the campaign against malaria. If a spring campaign against mosquitoes is planned, it is the part of wisdom to search out by blood examination all plasmodial carriers and put them through a rigorous course of quinine treatment during the autumn and winter to prevent spring and early summer relapses which are sure to discredit mosquito control, no matter how thorough, and to prevent mosquitoes from becoming infected.

At the beginning of the Anderson (Calif.) malaria campaign [28] an index was taken during June (1919) with the following results:

* Investigators concerned with malaria treatment should consult the League of Nations Bulletin of the Health Organization, Vol. VII, No. 1 (Feb. 1938), pp. 43-111.

PRELIMINARY MALARIAL INDEX, JUNE, 1919

	Blood smears			Histories			Number taking quinine
	—	+	%	—	+	%	%
Totals examined	90	29	25.2	33	86	72.2	53
Adults	62	16	20.6	29	50	64.1	40
10–15 years	18	10	35.7	3	25	80.3	10
Under 10 years	10	3	23.0	2	11	84.6	3

Positive cases were given quinine, 10 grains three times a day for seven days, then 20 grains every evening for seven days and 10 grains daily for ten weeks. At the close of the work 76 patients who had come under observation and treatment were again examined. Sixty-four, or 84.2 per cent, were negative and had had no recurrence of clinical symptoms. Successful cases averaged slightly better than 20 grains of quinine per day throughout the first week of treatment, while the failures took slightly over nine. Tertian malaria responded much more readily to treatment than aestivo-autumnal; every case of the former that came under observation being apparently cured Cured cases of aestivo-autumnal averaged 12 grains per day over 41 days, while the tertian averaged 11 grains per day over 39 days. Failures (all aestivo-autumnal) averaged 5 grains per day over 31 days.

In localities where it is not practicable to control mosquitoes, and that may be the case in rare instances, the use of quinine in small doses may be practiced in order to prevent malaria Carter [27] states that "it should be taken in doses of from 5 to 7 grains per day by grown people, 2 to 3 grains by children—less if small—during the malaria season, say June to November. Somewhat smaller doses will be efficient in places where the malaria is not bad. . . . In these doses it does no injury of any kind to those taking it."

Concerning the comparative cost of mosquito control and treatment of carriers, the following comparisons from the Rockefeller Foundation Review for 1918 are of interest. In Hamburg, Arkansas, a reduction of 97.4 per cent was secured by mosquito control at a cost of $1.45 per capita in 1917; for 1918 it was only 44 cents Neither this cost nor the next includes the overhead expenses of supervision by representatives of the Board. In Sunflower County, Mississippi, a demonstration was undertaken by the Foundation's International Health Board aimed at *curing* the carriers A control of 80 per cent was secured in the rural area at an initial per capita cost of $1 03 This would appear to throw favorable light on this method of malaria control, namely, treatment of carriers.

It should be remembered, however, that the administration of quinine

requires individual treatment and that strict supervision of a given population is difficult. Where large sums of money are necessary for carrying out a quinine program, it is well to consider first the possibility of correcting drainage defects and controlling the mosquito. When the funds for treatment have been exhausted, mosquito breeding continues as before, while if the same funds had been used to correct defects aimed at mosquito control, much good would have been accomplished even though the funds had been exhausted.

Treatment of malaria with plasmochin and with atebrine.—Plasmochin or plasmoquine, a synthetic drug said to be Aminoquinoline, was developed in 1925. It is used in malaria therapy as *Plasmochin Simplex* which is plasmochin hydrochloride, as *Plasmochin Compound* which when prepared in tablet form is such that each tablet contains ⅙ grain of plasmochin hydrochloride combined with 2 grains of quinine sulphate, and as *Chinoplasmin* where each tablet contains ⅙ grain of plasmochin hydrochloride and 4.5 grains of quinine sulphate. The last form of the drug seems to be the most effective. Plasmochin is reported to be more effective than quinine against the asexual forms of *P. vivax* in tertian malaria and *P. malariae* in quartan malaria, but while it attacks the crescents of *P. falciparum* as well as the gametocytes of the other forms it is not so good as quinine against the fever-producing forms (asexual forms) of *P. falciparum* in subtertian malaria.[28]

Atebrine or *atabrine,* an aminoacridin derivative, seems to attack asexual parasites more promptly than quinine or plasmochin, and is especially effective against the asexual forms of *P. falciparum* and seems to have a low relapse rate (Russell loc. cit.).

Though Komp and Clark[29] found that during a five-year period atebrine, or atebrine and plasmochin in combination, failed to prevent or control malaria under the conditions prevalent in Panama, when administered over a period long enough to include one of the cyclical upswings of the malaria rate, they consider it the drug of choice in the treatment of clinical cases.

Trypan Blue has lately come to the fore in the treatment of malaria and seems to have a definitely beneficial effect on chronic cases of subtertian malaria, though it is far from clear as to how this effect is produced.[30]

B. Filariasis

Filariasis.—An infection of nematode worms belonging to the family Filariidae is known as filariasis. The larval worms of this family are commonly known as microfilariae and occur in the circulatory and lymphatic systems, connective tissue layers and serous cavities of the vertebrate hosts. Among the species belonging to the family are *Mansonella*

ozzardi (Manson), said to be non-pathogenic, transmitted by *Aedes aegypti* (Linn.); *Acanthocheilonema perstans* (Manson), transmitted by *Culicoides austeni* Carter, Ingram and Macfie (see Chapter X); *Loa loa* (Cobbold), causing calabar swellings, transmitted by *Chrysops dimidiata* v. d. Wulp (see Capter XIV); *Onchocerca volvulus* Leuckart, transmitted by *Simulium damnosum* Theo. (see Chapter X); *Dirofilaria immitis* (Leidy), heartworm of dogs, transmitted by various species of mosquitoes including *Culex pipiens* Linn. and *Aedes aegypti* (Linn.); and most important species of all the filarial worms, *Wuchereria bancrofti* (Cobbold), transmitted by *Culex fatigans* Wied. and other species of mosquitoes.

Bancroft's Filaria.—*Wuchereria bancrofti* (Cobbold) is a widely distributed parasite of man, being particularly indigenous to Polynesia and many other tropical and subtropical areas of the globe In the United States only one endemic area is known, and that is a small area around Charleston, South Carolina.[31] Puerto Rico is reported to be one of the best-known endemic areas of filariasis in the Western Hemisphere, although it is not regarded as a major health problem there.[32]

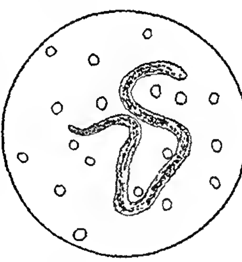

Fig. 79.—*Wuchereria bancrofti*, in human blood × 333

The microfilariae, first observed by Bancroft in 1876, measure about .3 mm. in length and from 7.5μ to 10μ in diameter (Fig. 79), and occur in the peripheral blood particularly at night, an observation which Manson made in 1877–1878. In the daytime the microfilariae are concentrated in the pulmonary vessels, the capillaries of the heart and other visceral organs. This nocturnal periodicity[33] enables night-flying mosquitoes such as *Culex fatigans* Wied. to suck up the parasites while biting Manson called attention to this adaptation and believed mosquitoes served as "nurses" for the filariae, and when the mosquitoes dropped into water and disintegrated the organisms were liberated and infection of human beings resulted from drinking infected water.

Having reached the stomach of the mosquito (more than a score of species are involved), the microfilariae lose their sac-like sheaths in an hour or two and proceed to invade the stomach wall, migrating thence to

the thoracic muscles where they become "sausage-shaped" and the internal organs develop. By the end of the second week the larvae have grown to about 1.5 mm. in length and migration from the thoracic muscles to the head is accomplished. Here the microfilariae lie coiled until the infected mosquito bites, when the larvae quickly slip down the labium and escape from the labellum upon the skin of the warm-blooded host. Here the microfilariae invade the skin and enter the peripheral blood capillaries. From the capillaries the parasites travel through the body until the lymphatics are reached. Here sexual maturity is achieved, mating takes place and young are produced. The female worms measure from 80 to 100 mm. in length, the males about 40 mm. Observers report that male and female worms are often found in tangles in nodular dilatations of the distal lymphatics, in lymphatic varices and in the glands themselves or even in the thoracic duct.

Faust[34] states that no manifest lesions or apparent symptoms are produced in the majority of cases, the only evidence of infection being the presence of the microfilariae in the peripheral blood. *Symptomless filariasis* is said to obtain "when the adult worms are so situated in the lymphatics that neither they nor their progeny obstruct the course of the lymph stream." When mechanical obstruction of the lymph flow occurs, *varix lymphaticus* is produced and in many cases *elephantiasis* of the lower extremities and the scrotum; in women, of the vulva and occasionally of the mammary glands.

Heartworm of dogs.—*Dirofilaria immitis* (Leidy) occurs in dogs and cats as well as various wild carnivores. The adult worms, females measuring from 25 to 30 cm. and the males 12 to 18 cm., invade the heart (right ventricle) and pulmonary artery of the host, where they often form tangled knots and may cause death.

The female worms like *Wuchereria bancrofti* are viviparous, and the microfilariae are found in the blood stream manifesting a nocturnal periodicity. The larvae similar in size to *W. bancrofti* are without sheaths. This species lends itself well to laboratory experimentation, since *Culex pipiens* Linn. is a suitable vector, and dogs are easily handled in the laboratory.

C. Yellow Fever

Yellow fever.—Yellow fever, also known as yellow jack, is one of the most dangerous diseases of man, occurring endemically in certain portions of Central and South America, the Caribbean littoral and the west coast of Africa. Epidemics of great magnitude have swept the southern United States, and Cuba suffered greatly from the disease for many years.

The disease is characterized by an abrupt primary rise of temperature of comparatively short duration, followed by a remission and

then a second febrile attack lasting much longer, accompanied by albuminuria, jaundice, bleeding of the gums, prostration, and a "black vomit."

Yellow fever mosquito-borne.—Although Dr. Carlos Finlay (loc. cit.) of Havana had quite early (1881) advanced a mosquito-transmission theory, and had carried on what we now know to have been incriminating experiments with nonimmunes, his theory was discredited until renewed interest in the same was given it by the work of the United States Army Yellow Fever Commission headed by Major Walter Reed in 1900. Reed [35] and his colleagues made a pre-report in which they state: "Since we here, for the first time, record a case in which a typical attack of yellow fever has followed the bite of an infected mosquito, within the usual period of incubation of the disease, and in which other sources of infection can be excluded, we feel confident that the publication of these observations must excite renewed interest in the mosquito theory of the propagation of yellow fever, as first proposed by Finlay."

Senate Document No 822 (Jan. 27, 1911) is concerned with yellow fever and contains a compilation of various publications by the Commission and others. In this document, McCaw gives the following account of the work of the Commission:

"In June, 1900, Major Reed was sent to Cuba as president of a board to study the infectious diseases of the country, but more especially yellow fever. Associated with him were Acting Asst Surgs James Carroll, Jesse W Lazear, and A. Agramonte.

"At this time the American authorities in Cuba had for a year and a half endeavored to diminish the disease and mortality of the Cuban towns, by general sanitary work, but while the health of the population showed distinct improvement and the mortality had greatly diminished, yellow fever apparently had been entirely unaffected by these measures In fact, owing to the large number of nonimmune foreigners, the disease was more frequent than usual in Habana and in Quemados near the camp of American troops, and many valuable lives of American officers and soldiers had been lost

"Reed was convinced from the first that general sanitary measures alone would not check the disease but that its transmission was probably due to an insect.

"In June, July, and August, 1900, the commission gave their entire attention to the bacteriological study of the blood of yellow-fever patients and the postmortem examinations of the organs of those dying with the disease. In 24 cases where the blood was repeatedly examined, as well as in 11 carefully studied autopsies, *Bacillus icteroides* was not discovered, nor was there any indication of the presence in the blood of a specific cause of the disease

"Application was made to General Leonard Wood, the military governor of Cuba, for permission to conduct experiments on nonimmune persons, and a liberal sum of money requested for the purpose of rewarding volunteers who would submit themselves to the experiment.

"It was indeed fortunate that the military governor of Cuba was a man who by his breadth of mind and special scientific training could readily appreciate the arguments of Major Reed as to the value of the proposed work.

"Money and full authority to proceed were promptly granted, and to the everlasting glory of the American soldier, volunteers from the Army offered themselves for experiment in plenty and with the utmost fearlessness.

"Before the arrangements were entirely completed, Dr. Carroll, a member of the commission, allowed himself to be bitten by a mosquito that 12 days previously had filled itself with the blood of a yellow-fever patient. He suffered from a very severe attack, and his was the first experimental case. Dr. Lazear also experimented on himself at the same time, but was not infected. Some days later, while in the yellow-fever ward, he was bitten by a mosquito and noted the fact carefully. He acquired the disease in its most terrible form and died a martyr to science and a true hero.

"No other fatality occurred among the brave men who, in the course of the experiments, willingly exposed themselves to the infection of the dreaded disease.

"A camp was especially constructed for the experiments about 4 miles from Habana, christened Camp Lazear in honor of the dead comrade. The inmates of the camp were put into most rigid quarantine and ample time was allowed to eliminate any possibility of the disease being brought in from Habana.

"The personnel consisted of three nurses and nine nonimmunes, all in the military service, and included two physicians.

"From time to time Spanish immigrants, newly arrived, were brought in [illegible] not [illegible] experimented upon, thus eliminating the possibility of any other disease than yellow fever complicating the case.

"The mosquitoes used were specially bred from the eggs and kept in a building screened by wire netting. When an insect was wanted for an experiment it was taken into a yellow-fever hospital and allowed to fill itself with the blood of a patient; afterwards at varying intervals from the time of this meal of blood it was purposely applied to nonimmunes in camp.

"In December, 5 cases of the disease were developed as the result of such applications; in January, 3, and in February, 2, making in all 10, exclusive of the cases of Drs. Carroll and Lazear. Immediately upon the appearance of the first recognized [illegible] experimental cases, the patient was [illegible] mile distant. Every [illegible] bites, and not in a single instance did yellow fever develop in the camp, except at the will of the experimenters

"The experiments were conducted at a season when there was the least chance of naturally acquiring the disease, and the mosquitoes used were kept active by maintaining them at a summer temperature.

"A completely mosquito-proof building was divided into two compartments by a wire-screen partition; infected insects were liberated on one side only. A brave nonimmune entered and remained long enough to allow himself to be bitten several times. He was attacked by yellow fever, while two susceptible men in the other compartment did not acquire the disease, although sleeping there 13 nights. This demonstrates in the simplest and most certain manner that the infectiousness of the building was due only to the presence of the insects.

"Every attempt was made to infect individuals by means of bedding, clothes, and other articles that had been used and soiled by patients suffering with virulent yellow fever.

"Volunteers slept in the room with and handled the most filthy articles for 20 nights, but not a symptom of yellow fever was noted among them, nor was their health in the slightest degree affected. Nevertheless they were not immune to the disease, for some of them were afterwards purposely infected by mosquito bites. This experiment indicates at once the uselessness of destroying valuable property for fear of infection. Had the people of the United States known this one fact 100 years ago, an enormous amount of money would have been saved to householders.

"Besides the experimental cases caused by mosquito bite, four nonimmunes were infected by injecting blood drawn directly from the veins of yellow-fever patients in the first two days of the disease, thus demonstrating the presence of an infectious agent in the blood at this early period of the attack.

"Even the blood serum of a patient, passed through a bacteria-proof filter, was found to be capable of causing yellow fever in another person."

The conclusions reached by the Commission follow:

"1. The mosquito (*C. fasciatus* = *Aëdes aegypti*) serves as the intermediate host for the parasite of yellow fever.

"2 Yellow fever is transmitted to the nonimmune individual by means of the bite of the mosquito that has previously fed on the blood of those sick with this disease.

"3. An interval of about 12 days or more after contamination appears to be necessary before the mosquito is capable of conveying the infection.

"4. The bite of the mosquito at an earlier period after contamination does not appear to confer any immunity against a subsequent attack.

"5. Yellow fever can also be experimentally produced by the subcutaneous injection of blood taken from the general circulation during the first and second days of this disease.

"6. An attack of yellow fever, produced by the bite of the mosquito, confers immunity against the subsequent injection of the blood of an individual suffering from the nonexperimental form of this disease.

"7. The period of incubation in 13 cases of experimental yellow fever has varied from 41 hours to 5 days and 17 hours.

"8. Yellow fever is not conveyed by fomites, and hence disinfection of articles of clothing, bedding, or merchandise, supposedly contaminated by contact with those sick with this disease, is unnecessary.

"9. A house may be said to be infected with yellow fever only when there are present within its walls contaminated mosquitoes capable of conveying the parasite of this disease.

"10 The spread of yellow fever can be most effectually controlled by measures directed to the destruction of mosquitoes and the protection of the sick against the bites of these insects

"11. While the mode of propagation of yellow fever has now been definitely determined, the specific cause of this disease remains to be discovered."

Other mosquito vectors.—Prior to 1928 (see Chapter I) no experimental animal other than man was known to be susceptible to yellow fever. With the discovery that the Indian monkey, *Pithecus rhesus*, was susceptible and a score of other species of monkeys and white mice as well, experimentation with various species of mosquitoes

grew apace. Soper et al. 1933 [36] give a list of all species of mosquitoes with which experiments on the transmission of yellow-fever virus were made, and of these the following gave positive results of biting tests: *Aedes aegypti* (Linn.), *A. africanus* Theob., *A. albopictus* (Skuse), *A. apicoannulatus* (Edw.) (renamed *A. stokesi* Evans), *A. fluviatilis* (Lutz), *A. luteocephalus* Newst., *A. scapularis* (Rondani), *A. scutellaris* Theob. (same as *albopictus*), *A. simpsoni* Theob., *A. taeniorhynchus* (Wied.) (?), *A. vittatus* (Bigot), *Culex thalassius* Theob., *Eretmapodites chrysogaster* Graham, and *Mansonia africana* (Theob.), *Culex fatigans* Wied., and *Psorophora ferox* (Humboldt) (?).

The infection.—The search for the causal agent of yellow fever has been carried on most assiduously for many years and various discoveries were announced from time to time. Sanarelli in 1897 declared the organism to be *Bacillus icteroides;* this was amply disproved by the U. S. Yellow Fever Commission in 1900. Seidelin in 1909 described *Paraplasma flavigenum* as the causal agent and in 1919 Noguchi came to the conclusion that a spirochaete, *Leptospira icteroides* Noguchi, was the cause of yellow fever. This turned out to be the cause of Weil's disease or infectious jaundice. Yellow fever is now classed among the virus diseases.

The virus is believed to be present in the circulation only during the first three days of the disease. *Aedes aegypti* (Linn.) reared from eggs in the laboratory and fed by Stokes, Bauer and Hudson (loc. cit.) on infected monkeys on the first or second day of the fever, invariably became infective. They found that the mosquitoes were infective 16 days after feeding on an infected animal and remained so until death, one mosquito producing a fatal infection in two monkeys 85 and 92 days after the original infective meal.

Jungle yellow fever.—Yellow fever is generally regarded as an urban or house disease which is transmitted solely by *Aedes aegypti* (Linn.), a domestic mosquito which breeds largely in artificial containers in and about human habitations. Control seemed simple enough with meticulous inspection. The Rockefeller Foundation reported [37] that prior to 1929 the belief was expressed that yellow fever was not only fast disappearing as a human menace but that it had been practically eliminated. "In 1925 only three cases of yellow fever were reported from the entire Western Hemisphere; in the eleven months following April, 1927, no cases were reported; and it was assumed that the battle, which had cost the lives of research workers and millions of dollars, was practically won. Then almost without warning, the South American jungle struck back [Soper and associates, 1933 (loc. cit.)], and in a few years' time the epidemiological strategy of the battle had to be completely altered." It is pointed out that vast areas of the hinterland of both South America and Africa are endemic centers of yellow fever. Burke [38] (1937) studied an

epidemic involving 201 cases of yellow fever of the jungle type in the absence of *Aedes aegypti* (Linn.) on the Planalto of Matto Grosso, Brazil, during the seasons of 1934 and 1935. He reports that the identity of the disease was definitely established, the only difference being in the conditions under which infection occurs. "The paucity of human population in the infected district and the scattered distribution of cases in both time and space, together with the isolated circumstances attending many cases argue against man being the only vertebrate host involved. The sera from five *Cebus* monkeys captured for this study in known infected districts all gave positive protection test results, indicating immunity naturally acquired in the jungle. All available evidence points to infection occurring either in clearings next to uncleared jungle or in the jungle itself, especially during working hours." The Rockefeller Foundation (loc. cit.) points out that jungle yellow fever must be considered as a possible permanent source of virus for the reinfection of cities and towns where high densities of *Aedes oegypti* (Linn.) mosquitoes are tolerated.

Other than *Aedes aegypti* (Linn.) successful transmission by the bite has been obtained by *Aedes scopularis* (Rondani), *Aedes fluviatilis* (Lutz), *Aedes leucocelaenus* D and S. and *Haemagogus capricornii* (Lutz). *Aedes leucocelaenus* D and S and *Haemagogus capricornii* (Lutz), both forest-inhabiting mosquitoes, were incriminated by Shannon, Whitman and Franca [39] during the 1938 outbreak of jungle yellow fever in the state of Rio de Janeiro, Brazil. The presence of the virus in mosquitoes caught in the jungle was demonstrated.

D. Dengue Fever

Dengue fever.—Dengue, also known as breakbone fever or dandy fever, is a widespread disease of tropical and subtropical regions, particularly the Philippines, but it is also found in temperate climates. Although notably a coastal disease, it may occur inland. The number of cases in the 1922 epidemic in the state of Texas was estimated at between 500,000 and 600,000,[40] originating in Galveston during the second week of June, spreading later to other parts of the state and beginning to abate late in September, ending in late autumn.

The disease is characterized by its sudden attack, severe rheumatic pains in the joints and limbs, headache, high fever; a remission of about two days follows the first attack of three days, the second attack lasts usually but a day and is accompanied by a rapidly spreading rash. The "saddle back" type of fever though quite common is not constant. The entire course may be run in five to six days. Although a disease of much economic importance because of its debilitating effects, the death rate is very low. It is caused by a filterable virus as shown by Ashburn and Craig 1907.[41] The virus is said to be present during the first three days of

the fever, hence the mosquito vector must bite the patient during this time in order to become infected.

Mosquito transmission.—Transmission experiments conducted by Chandler and Rice (loc. cit.) with *Aedes aegypti* (Linn.) were successful in four out of six cases, the mosquitoes having fed on patients in the second to fifth days of the disease.

Simmons, St. John and Reynolds [42] (1931) found that all lots of *Aedes aegypti* (Linn.) that fed on blood from experimental cases of dengue during the first forty-eight hours of the disease became infected. The mosquito is able to transmit the infection after an incubation period of 11 days, though Chandler and Rice (loc. cit.) state that mosquitoes succeeded in transmitting the disease in from twenty-four to ninety-six hours. Infected mosquitoes remain infected as long as they live. The infection has been transmitted 174 days after infection and *Aedes aegypti* (Linn.) has been kept alive for seven months. (Simmons et al., loc. cit., p. 22.)

Graham [43] (1902) was the first to demonstrate that mosquitoes transmit dengue by the bite.

The incubation period in experimentally infected cases varies from three to eight days. Simmons et al. give the average incubation period at 5.66 days; average duration of the fever, 4.8 days. The virus is not transmitted from infected female *Aedes aegypti* (Linn.) through the egg to the offspring, neither does contamination of the skin by dengue virus from crushed *Aedes aegypti* (Linn.) result in infection. Immunity is believed to be conferred by an attack of dengue "in a large majority of cases."

The investigations of Simmons, St. John and Reynolds prove that *Aedes albopictus* (Skuse) is an important vector of dengue, also that *Culex fatigans* Wied., hitherto regarded as an important vector, is of no consequence.

E. Bird Malarias

Bird malarias.—Many species of birds inclusive of crows, sparrows, finches, blackbirds and canaries, are subject to infections known as bird malaria. These infections are caused by haematozoa belonging to the genus *Plasmodium*, e.g., *P. cathemerium* Hartman and *P. praecox* (*relictum*) Grassi and Feletti, transmitted by mosquitoes, *Culex pipiens* Linn. and *C. fatigans* Wied. Since the behavior of these species of plasmodia of avian malaria resembles closely that of the plasmodia of human malaria, experimental work with these easily manipulated forms is helpful in the solution of important problems of human malaria.[44] Indeed, it was experimental work with bird malaria which enabled MacCallum and Ross to make famous discoveries in the field of human malaria as already

stated. Huff (1933, loc. cit.) has shown that "the degree of infection in a susceptible mosquito (*Culex pipiens* Linn.) is determined by some inherent characteristic of the individual in quite a constant manner in spite of differences in the numbers of gametocytes ingested and of whether or not there has been previous infection." Huff's experiments were with *Plasmodium cathemerium* and *P. elongatum* Huff. He points out that these findings may have a bearing on the explanation of differences in the ability to transmit human malaria by different geographical races of *Anopheles*.

Other malaria-like infections of birds are caused by *Haemoproteus*, e g , *Haemoproteus columboe* Celli and San Felice of pigeons and doves, transmitted by a louse fly, *Pseudolynchia canariensis* (Macq.); also quail malaria caused by *Haemoproteus lophortyx* O'Roke carried by *Lynchia hirsuta* Ferris, the louse fly of quail. (See Chapter XIX.) A malaria-like disease of ducks is caused by *Leucocytozoön anatis* Wickware and is carried by a simuliid fly, *Simulium venustum* Say. (See Chapter X.)

F. Equine Encephalomyelitis

Equine encephalomyelitis.—Equine encephalomyelitis is a disease of wide distribution, the causative agent of which is a filterable virus with neurotropic properties as shown by Meyer, Haring and Howitt,[45] whose description of symptoms follows. "Preceding the onset of symptoms which attract attention, the temperature may be found to vary from 103° F. to 107° F. Not infrequently when the horse shows signs of drooping of the head, sleepiness and circling motion or other psychic and motoric disturbances, the body temperature may be normal. The pulse and respiration are usually accelerated Quite often the animol rests against the woll or corner ond may show backward ond sideways motions. Muscular twitchings are quite common. Many of the horses ore down on the second or third day and may or may not get up when pressed to do so. Paresis of the lips and drooling are frequently noted. Mastication and swallowing may or may not be impaired, but grinding of the teeth is quite regularly observed. The conjunctiva is always infected and frequently icteric or grayish and studded with petechiae or ecchymoses. In the mild cases which were able to rise, recovery was as a rule uneventful but about half were so severe that they terminoted fatally in 3 to 8 days or were destroyed for humane reasons."

Believing that bloodsucking insects might be instrumental in the tronsmission of the virus, the author conducted tests during the late summer of 1932 (Herms, Wheeler and Herms 1934).[46] In these tests horseflies, *Tabanus punctifer* O. S., and horn flies, *Haemotobio serrata* Desv., were used—oll with negative results.

Early in 1933 Kelser[47] proved that the disease can be transmitted by

Aedes oegypti (Linn.) not only from infected guinea pigs to normal guinea pigs but also to n horse which eontracted the disease and died within five days after the onset of symptoms. Blood drawn from the horse at the height of the fever nnd injected into a guinea pig produced the disense and mosquitoes fed on the horse during the period of high temperature and aubsequently fed on n normal guinea pig likewise produced the disease. The largest percentage of deaths among the guinea pigs bitten by infected mosquitoes occurred on the sixth day following the infective mosquito bite. The mosquitoes were found to be capable of producing the disease as early ns six days nnd remained infectious for at least 36 days. Kelser pointed out that it is possible that the mosquitoes, when once infected, may remain infectious the rest of their lives as is the ease in yellow fever and dengue.

Followiag the work of Kelser the nuthor conducted further tests, using *Anopheles maculipennis* Meigen nnd *Aedes dorsalis* (Meigea), a salt-marsh mosquito, bred from larvae taken from a salt marsh. Again all results were negative (Herms, Wheeler and Herms, loc. cit.). However, later tests (unpublished) made in October, 1934, give evidence of six successful transmissions out of 29 (guinen pig to guinea pig) secured with *Aedes dorsolis* (Meigen) bred from fresh-water larvae. The elapsed time between initial feeding on nn inoculated pig and feeding on a normal pig was six days in four of the positive enses nnd twelve days in the remaining two. From four to fifty mosquitoes were used. Investigations made by Madsen, Knowlton and Rowe [48] with *A. dorsalis* (Meigen) also indieate that this species may be n vector of the virus althougb most tests failed, yet 2.5 per cent of the total trinls (with guinea pigs) were positive, with incubation period varying between 9 nnd 19 days. Tests made by these authors with *Aedes nigromaculis* (Ludlow) gave 5.8 per cent positive transmissions, with incubation period varying between 4 and 10 days. Merrill, Lacaillade and Ten Broeck [49] have demonstrated in repeated tests that *Aedes sollicitans* (Walker), a common Atlantic coast salt-marsh mosquito, will transmit botb eastern and western strains of the virus from infected to normal guinea pigs. Transmission was obtained witb the eastern virus 11 days after the initial feeding and at later periods. *Aedes cantator* (Coq.), another salt-marsh breeder, was shown to transmit the eastern virus, though less readily. These authors have demonstrated a 1,000- to 10,000-fold increase of the virus within the bodies of both *Aedes aegypti* (Linn.) (western strain virus) and *A. sollicitans* (Walker) (eastern atrain virus). They report 63 days as being the longest period during wbich *Aedes aegypti* (Linn.) is capable of transmitting the western strain. Madsen and Knowlton [50] were successful in transmitting the western virus to guinea pigs by the bite of *Aedes nigromaculis* (Ludlow). Simmons, Reynolds, and Cornell [51] demon-

strated that *Aedes albopictus* (Skuse) could transmit the western virus. Kelser (Science, Feb. 12, 1937) reported studies definitely proving the ability of *Aedes taeniorhynchus* (Wied.) to transmit the "western" type of equine encephalomyelitis from guinea pig to guinea pig.

It is highly suggestive that Syverton and Berry [52] were able to transmit the western strain of the virus to a ground squirrel, *Citellus richardsoni* (Sabine) through the bite of ticks, *Dermacentor andersoni* Stiles. The animal died five days after the ticks, which had fed on an inoculated guinea pig, were placed on the animal. Tyzzer, Sellards and Bennett [53] have recently demonstrated the natural occurrence of the infection in the ring-necked pheasant. Man is evidently susceptible to the infection.[54]

G. Fowl-pox

Fowl-pox.—Fowl-pox, an important virus disease of poultry, while spread in various ways such as contact between diseased and healthy birds, may also be spread, according to Brody,[55] by *Aedes stimulans* (Walker) by intermittent feeding, harboring the virus in or on its body for at least two days following an infective meal, and by *Aedes aegypti* (Linn.), which can definitely transmit the virus more than once during its life. The latter species is able to transmit the disease within one hour after an infective meal and continues to be infective from 39 to 21 days.

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CHAPTER XIII

MOSQUITO ABATEMENT

Historical.—L. O. Howard,[1] for many years (1894–1927) chief of the United States Bureau of Entomology, records "an experiment against mosquitoes" which he conducted in 1892. Howard "sprinkled four ounces of coal oil upon the surface of the pond" which he found "contained 60 square feet. . . . The pool which upon the evening of the 5th (July) had been teeming with animal life, contained no living insects during the following ten days. The kerosene, curiously enough, seemed to exercise no deterrent effect upon the adult female mosquitoes They still continued to attempt to deposit eggs and in this attempt were destroyed This is in my opinion a most important point, and one which has hardly been anticipated." This experiment was made in the Catskill Mountains of New York at an elevation of about 2,500 feet.

The work of Gorgas in controlling yellow fever in Havana in 1901 and that of Gorgas and Le Prince [2] in controlling yellow fever and malaria in the Panama Canal Zone attracted much attention to the subject of mosquito abatement. Ross (1902), in his book "Mosquito brigades and how to organize them," gave much practical information regarding methods of mosquito control.

Public interest in the United States was greatly stimulated by the appearance of J. B. Smith's "Report on the mosquitoes of New Jersey" in 1904. Salt marsh mosquito abatement on the Pacific coast began at Burlingame, California, in 1905 [3] and in 1910 [4] the first specific malaria-mosquito control work was begun by the writer at Penryn (Placer County), California. As early as 1910 the writer called attention to the danger from malaria due to seepage from poorly constructed irrigation ditches and canals in California. "The use of metal, cement, or tile irrigation ditches, which prevent lateral flow except where wanted, will help greatly in lessening the vast number of (malaria) mosquitoes now produced in or by poorly kept ditches." Farmers of northern California were admonished to "pay more attention to the improvement of their irrigation methods."

In 1913 [5] Carter of the United States Public Health Service began to make malaria surveys in Virginia and North Carolina In 1914 a Federal appropriation of $16,000 was provided for malaria investigations by the Public Health Service; 22 surveys and three malaria control demonstra-

tions were made in seven states in that year. From 1914 to 1928 the United States Public Health Service conducted directly or in coöperation mosquito-malaria control work in 343 communities in 17 states, and including surveys and investigations in 667 communities in 24 states.

Organization for abatement work.—Before actual mosquito abatement work is undertaken, it must be planned and organized.[6] There must be an adequate preliminary survey. The services of an experienced and practical mosquito-abatement expert should be secured to make this survey. The expenses for the preliminary survey are usually defrayed from funds raised by public subscription.

The preliminary report should include data and recommendations on the following matters:

1. The boundaries of the area which should be included within the project.
2. The population, area, and assessed valuation of the proposed district.
3. The location and areas of the principal breeding marshes.
4. Tentative suggestions as to the best method of control for each principal breeding marsh.
5. The amount and types of domestic breeding, and measures for abatement
6. The particular species of mosquitoes involved such as *Culex tarsalis* Coq. and *Culex pipiens* Linn. with a brief discussion of their breeding habits
7. The probable organization that will be required, including personnel and equipment.
8. Detailed preliminary estimates of cost, both for permanent work (including capital outlays) and for regular maintenance. With these should be submitted comparative costs for districts of similar size and conditions.
9. The economic losses caused by mosquitoes in the proposed district, and the economic savings which should result from adequate mosquito abatement measures.

Personnel.—The general supervision of the work, particularly as to policies and finance, is usually in the hands of a board or commission appointed in various ways in different states. The proponents of the undertaking should make the proper representations to the appointing power or powers, so that only citizens of outstanding character and ability are appointed. It is desirable that the members of the board or commission serve without compensation, except that expenses incurred in the performance of duty should be defrayed. In making selections it is well to include an outstanding physician or two, a public-minded attorney, a respected and able civil engineer, and a successful business man—all should have a deserved reputation for unselfish public service.

The most important duty of the Board or Commission is the selection of the executive officer, who for the larger districts should have at least the following qualifications: (1) agreeable personality and honesty, (2) successful experience in mosquito abatement work, (3) administrative ability, (4) training in entomology and sanitary engineering. For smaller districts this officer may well be of the working-foreman type.

In large districts it is necessary to subdivide the force into divisions which can be handled by one man, a responsible *foremon* or *inspector*, and a crew of laborers. The foreman should be a full-time man, must be active, energetic, interested in his work and able to handle his men in ditching or oiling work. As he is in immediate contact with the public, he must have a good personality, and must be able to get along with people. He will require much "backbone," plus self-restraint and patience. He must be physically equal to sustained activity in the field, for the work is frequently arduous.

Adequate office facilities must be provided, inclusive of clerical and telephone service, for public contact and business purposes. Detailed maps of the district must be available, a reporting system, and a bookkeeping system in conformance with legal requirements must be developed. The office should maintain a skillful and continuous program of publicity and public education.

Inspections for mosquito breeding.—Inspections for the purpose of finding breeding places in organized mosquito abatement districts are either made upon the receipt of complaints or for routine purposes. The inspector should be guided by the nature of the complaint, (1) mosquitoes annoying at night, affecting sleep, and (2) annoying during the daytime or toward evening, while working in the garden or watering the lawn In the first instance it is probably a domestic fresh water species, breeding on the premises or in the immediate vicinity. In the second instance it is probably a salt-marsh species, if such exists in or near the district. In the previous chapter exceptions to this rule are discussed, particularly the spring dispersal flights of Anopheles. Obviously the inspector must have a thorough knowledge of the species of mosquitoes and be well informed concerning breeding habits. When complaints are received, the inspector should visit the premises and if possible capture mosquitoes for identification, so as to simplify inspection for larvae and to insure effective abatement.

In searching for adult mosquitoes for species determination it is important to remember that few species are active during the day, hence one must search for them in dark, cool and moist places, under houses, in basements and cellars, behind pictures, in closets and dark corners. An electric flashlight is very useful. *Aedes dorsalis* (Meigen) and other day fliers often hide in shrubbery and may be found by shaking bushes and vines or kicking weeds The mosquitoes may be collected in small cyanide bottles or by means of a sucking tube with an extension rubber tube.

Inspections, whether due to complaint or as a matter of routine, must be thoroughly and intelligently carried out; the breeding may be occurring in a rain barrel, a lily pond, or a concealed cesspool; it may be taking

place in a concealed chamber fed by a natural spring; in an abandoned well, a broken or clogged sewer or drain; floor boards may have to be removed.

The work of routine or house-to-house inspection must be properly organized for efficient and economical coverage. The inspectors must be intelligent, well trained technically and must be capable of meeting all sorts of people.

In inspecting large tracts of marsh to locate the precise producing areas, it is always advisable to mark off the marsh into definite sections, which can be examined one at a time, so that no portion is overlooked Breeding areas, when located, are marked by setting up stakes in the center of the breeding area for the crew of oilers which follow, or for future reinspection.

Essentials of mosquito abatement.—Bearing in mind the fact that no mosquito ever came into existence without water in which its larval stage was completed, and that a very small quantity of water, even a thimbleful, may serve the purpose very well, the control of collections of suitable water available to mosquitoes is a matter of importance. The objective of mosquito abatement operations is the elimination of mosquito production. The abatement method must be suited to the mosquito involved. Marsh drainage or the usual oil treatments would be ineffective in the control of tree-hole species such as *Aedes varipalpus* (Coq.) where tree surgery is indicated.

Other principles of importance in mosquito control operations under temperate-zone conditions are as follows:

1 The work should be started early in the spring with the first appearance of larvae, and kept ahead of the mosquitoes

2 At the end of the breeding season efforts should be intensified to reduce the last brood as far as possible so as to have fewer overwintering mosquitoes to start next year's brood.

3. Use the winter months for maintenance work on drainage systems; for construction of new drains and permanent structures; and for planning the following year's work

Drainage.—The removal of water which may collect and produce mosquitoes presents a distinct problem in nearly every case. The type of drainage required in most cases will generally not require technical skill and would probably not commend itself to the average civil engineer. There are, however, drainage projects of considerable proportions which will require engineering skill; such skill is eminently necessary for large-scale salt-marsh drainage operations where land reclamation calls for dykes, drainage canals, pumps, tide gates and the like. Unless the executive officer is himself an engineer, properly qualified engineering talent must be employed to secure effective control.

In the case of a swamp caused by springs, a system of *deep* circumferential cut-off drains is recommended in order to intercept the seepage water and conduct it around the wet area. Where streams debouch from the hills on to a flat plain or valley, water from heavy rains, particularly in the spring, tends to spread out and leaves temporary pools which may produce mosquitoes. Usually these temporary pools can be more economically controlled by oiling, but in some cases at least drains may be dug which lead back into the main stream at a lower elevation. These ditches will usually require considerable maintenance.

Mosquito breeding in rolling country is commonly due to artificial obstructions, particularly railroad or highway embankments with improperly placed culverts. Usually culverts are set too high so that pools or swampy areas are formed on the upper side of the embankment. Corrections are usually not speedily made if at all, hence heavy oiling is a necessary remedy.

In some swampy situations because of small or negative gradients, drainage becomes very difficult or impossible. In such cases *sumpage ditches* or sumpage wells may be constructed and the collected water may then be heavily oiled. Surface water may also persist because of hardpan (impervious subsoil, etc.), in which case *vertical drainage* may be resorted to by digging sumpage wells, or by blasting.

Drain ditches.—The purpose of laying out drain ditches is to secure effective and economical drainage. Where the general slope of the ground is appreciable to the eye, this is usually a simple matter, i.e., following the low points to a place where the drainaga water can be disposed of into some natural water course or other situation where there is sufficient fall to carry away the water. Laterals are then run from the main drain by the shortest distance to connect up with low spots or wet areas. The bottom of the main drain ditch must be kept deep enough so that the laterals can reach all the low spots in the area to be drained.

For most of the ordinary ditching for mosquito control transit and level are unnecessary. All that one needs are a few long stakes, 500 feet or more of stout chalk line or strong cotton cord, for line, and a hand level with a ten foot board marked in feet and inches. If drains of considerable size and yardage are to be excavated, the usual surveying methods are employed and the work, perhaps, should be done under contract with power machinery.

Hand labor, using pick and shovel, serves most purposes very well. As a rule the square-point long-handled shovel is to be preferred over the round-point shovel for ditching. Under some conditions long-handled spades may be satisfactory. Mattocks may be found useful in some soils.

In many cases, more or less dense vegetation has to be cut down and cleared before ditching can be performed with any speed or economy.

Heavy grass or weeds may be cut with scythe, sickle or machete. In open fields a horse-drawn hay mower, if available near by, may be economical. For brush, either axes, brush hooks or machete may be used. The machete, however, is a dangerous tool in the hands of a man not accustomed to its use.

Dense grass and some forms of brush may also be killed by applying stove distillates or Diesel oils, which are toxic to vegetation. After killing and drying, the dry vegetation can be burned, particularly if a sprayer is used with distillate to augment the blaze. Arsenical weed killers such as sodium arsenite, or an acid solution of arsenious chloride, may be used where there is no danger of cattle or other herbivorous animals being affected. However, in any agricultural community the use of arsenical weed killers should be avoided.

Weed burners, constructed on somewhat the same principle as the plumber's blow torch, and capable of throwing a blue flame two or three feet long, can be used for clearing dense vegetation, but the general experience seems to be that they are more expensive than other methods of clearing. If burning is to be done due consideration must be given to the nesting season and nesting habits of wild life.

Ditching with dynamite.—Swampy ground too wet to hold up a team may often be economically ditched with dynamite. Special directions will have to be followed and trial shots will be necessary as a rule to determine the correct depth of holes, their distance apart and the amount of dynamite per hole. The most satisfactory results are obtained by using 50 to 60 per cent straight nitroglycerine dynamite, fired by self-propagating detonation.

Dynamite ditch construction is advantageous in that a ditch can be blown through land with stumps, boulders, etc., without first removing these obstructions, by placing heavier loads at these points.

Maintenance of ditches.—After the drainage ditch is constructed, it must be maintained in effective working order. Three main conditions making constant maintenance necessary are:

(a) Growth of vegetation,
(b) Caving or sloughing of banks,
(c) Artificial obstructions

Under some conditions growth of vegetation in and adjacent to ditches is not a problem, but as a rule ditches will require clearing several times a year in order to keep them free from obstructing growths. In tropical or semi-tropical countries the problem of keeping drains free from vegetation is most difficult, and the source of considerable maintenance expense.

While weed killers may be helpful under some conditions, dependence

must be placed in most cases on hand labor in cutting down and clearing out growths. The frequency of clearing will depend, of course, on local soil and climatic conditions, and it will be difficult as a rule to estimate in advance what the annual cost of maintenance of ditches will be.

Caving or sloughing of ditch banks is apt to occur in new ditches, for the first year or two. After that the banks usually become fairly stable, and but little further trouble is encountered, unless cattle are pastured along the ditches. In that case they may break down the ditch banks and cause some trouble.

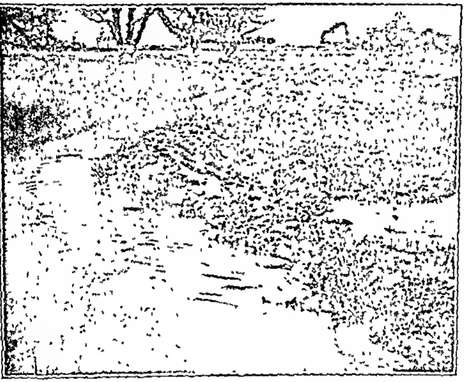

FIG. 80.—Breaks in the irrigation ditch are responsible for considerable inundation, producing favorable breeding places for mosquitoes. The rapidly running water in the ditch is unfavorable for mosquitoes.

Artificial obstructions are as a rule frequent only in the vicinity of public roads near a city or town. It is surprising the number of people who will haul refuse away from their homes out into the country and dump it. Usually they will dump it in a ditch close to a road, and block the ditch completely or partially. The ditch thereupon becomes a mosquito breeder.

Frequent inspection of drainage ditches, say at least once every two or three weeks during the breeding season, should be carried on, and all obstructions to flow, whether natural or artificial, removed promptly.

During the winter all ditches should be gone over carefully and trimmed to grade and the proper side slopes of banks, so as to enter each breeding season with all ditches in first-class order.

Irrigation.—Where irrigation is properly practiced with due attention to the economical use of water and good farm practice, there need be no mosquito breeding and consequent malaria menace. However, when seepage results from breaks in ditches and particularly from side-hill canals, ideal swampy areas are produced and cattle and horses leave water-filled hoof prints, an ideal breeding situation for *Anopheles maculipennis* Meigen. Because of the breeding habits (in seepage water) of this important malaria-bearing mosquito, poorly constructed and improperly operated or leaking irrigation ditches commonly account for malaria in the neighborhood. (Fig. 80.)

Wilson in "Irrigation Engineering" (John Wiley & Son) points out that "malarial effects are not attributable directly to the results of irrigation where it is economically and properly practiced—where care is taken to irrigate only land which has an open soil and such slopes and natural drainage as to prevent waterlogging, no unhealthy effects will result. . . . It is desirable, in order to mitigate the possible evil effects of irrigation, to keep the canal as much as possible within soil so that its surface level may be low, and thus only raise the sub-surface water plane to the least height practicable; that earth wanted to complete embankments be never taken from excavations or borrow-pits except where such localities admit readily of drainage."

Cheapness of water invites wastefulness and carelessness. Leaky pipe lines, leaking ditches, and excessive application will not be tolerated where water is more expensive. As the cost of water increases or the public health significance is appreciated, improvement in irrigation practice follows; where a few years ago dirt ditches permitted seepage and often became weed grown and little attention was given to drainage, there are now concrete ditches with intelligent attention to drainage.

It may be pointed out that there is a distinct difference between agricultural drainage and mosquito abatement drainage as applied to irrigation districts. Agricultural drainage is concerned merely with the problem of lowering the ground water level to a point where crops can be raised successfully. Frequently considerable quantities of mosquito-breeding water remain, often in the drains themselves. (Fig. 81.) Such drainage consists usually of large, deep main drains with comparatively few laterals. Mosquito abatement drainage, on the other hand, is a matter of more careful attention to detail, with great care to obtain uniform grades and smooth bottoms for the drains, so as to avoid mosquito breeding.

Salt-marsh drainage.—Salt-marsh drainage requires special study

and experience because of tidal action, soil conditions, differences in behavior of salt-marsh mosquitoes and other factors. The rich reward in comfort and reclaimed land has given incentive to salt-marsh mosquito abatement. Strong public-spirited organizations have given marked support to this work on the Atlantic coast as well as on the Pacific, particularly in New Jersey and California.

These marshes include vast areas of tidal marshes affected by salt or brackish water along the shores of oceans and particularly the various bays, sounds and estuaries. The effect of daily (diurnal) and spring tides resulting in fluctuations of water level is the principal feature distinguishing these from fresh-water marshes, although other characteristics are of importance such as the salt-marsh vegetation.

FIG 81.—Drainage water resulting from irrigation, a source of myriads of mosquitoes The small ditch in the background will remove the difficulty.

While salt marshes appear to be flat (Figs. 82 and 83), there is a gradual slope between low tide level and the adjacent dry land. For practical purposes these marshes may be divided into two main areas, the area subjected to daily tidal action where mosquito breeding seldom occurs and the area between the elevation of mean high tidal water and the elevation of the extreme high tides. It is in this latter area where practically all the breeding of salt-marsh mosquitoes occurs.

Mosquito control operators concerned with projects involving salt marshes must acquaint themselves thoroughly with tidal phenomena. These vary in range and type in different parts of the world. The so-called "spring" tides, one or two of which occur each month, are the tides which fill pools along the upper portions of the marshes, and in these pools the principal salt-marsh mosquito breeding occurs.

The dates, times and heights of the monthly highest tides are im-

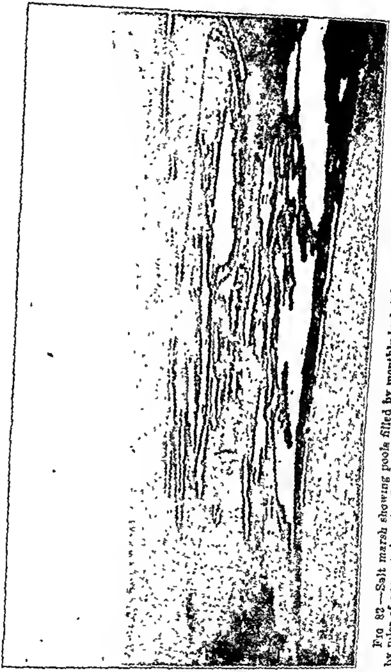

Fig 82.—Salt marsh showing pools filled by monthly high tide. Ditch excavation begun (ditches outlined by piles of excavated mud). Compare with Fig 38 showing same area after ditching was completed. (Photograph by H. F Gray.)

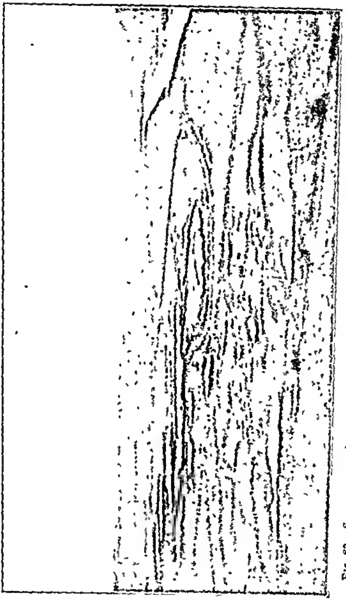

FIG 83.—Same area as shown in Fig 82 after ditching was completed Breeding pools are emptied of water and low areas overgrown with *Salicornia* and other marsh vegetation are drained. (Photograph by H F Gray)

portant in their bearing on the approximate time of emergence of a new crop of salt-marsh mosquitoes. It should be the invariable practice during the salt-marsh mosquito breeding season to inspect all known or suspected marsh breeding areas, beginning about two days *after* the highest tide and completing the inspection within six or seven days. The delay of two days is for the purpose of giving the larvae opportunity to develop to a sufficient size to be easily seen with the unaided eye. As under favorable conditions the time from egg hatching to emergence may be as short as eight days, it is obvious that if a flight is to be prevented, the inspection and necessary control measures must be completed before the time of emergence.

Because salt-marsh mosquito control involves the location of dykes and tide gates, *the knowledge of the dates, times, and heights of both the lowest tides and the highest tides, particularly of "storm tides," the combined effect of "spring tides" and piling up of water on shore due to high winds and river flood waters as well, is important.*

Marsh vegetation is often very dense and interferes with inspection and oiling, hence burning is usually recommended. It must be borne in mind that peat deposits commonly occur, and if the water level has been lowered due to drainage, which is usually practiced, dry peat may ignite and a peat fire result. Peat fires can only be extinguished by flooding, [illegible] just mentioned, a fire hazard may result, but also an additional hazard may follow in the shrinkage of the soil and the formation of "cracks." These cracks may be several feet in depth and may contain water in which mosquitoes breed in abundance. Such cracks are difficult and expensive to oil, hence an area of marsh that has cracked due to drainage operations should be plowed so as to break up the surface and fill in the cracks. An occasional disking after the initial plowing is recommended. For mosquito abatement purposes it is desirable to lower the water level [illegible] there is a peat fire hazard. Drainage and burning [illegible] due regard for wild life conservation.

[illegible] marsh drainage the marsh is opened up by ditches to the [illegible] flow of tides so as to eliminate standing water suitable for mosquito breeding. In the *reclamation type* the area to be drained is surrounded on the low sides by a dyke which is pierced in one or more places by outlet structures, *tide gates*, which permit water behind the dyke to run out at low tides, but prevent the return flow at high tides. Suitable drainage

ditches are dug to conduct water to the outlets (Fig. 84). The reclaimed marsh may be used for agricultural or industrial purposes.

Filling and pumping.—In almost all mosquito abatement work low wet areas will be encountered which cannot be economically drained. Although some such places may be ponded and the water stocked with top minnows, usually the most satisfactory method is filling. (Fig. 85.) Most smaller holes such as borrow-pits can be filled in by hand shoveling;

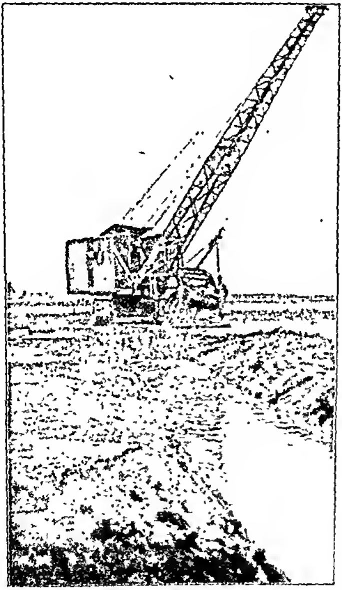

FIG. 84.—Salt marsh drainage operations with drag line mounted on timber mats to prevent sinking in mud. The bucket is about to cut into a breeding pool which will be drained into ditch in foreground. (Photograph by H. F. Gray.)

larger holes may be filled by means of a horse-drawn scraper. If sanitarily handled, municipal garbage and refuse may be used in a "fill and cover" method. Such fills are covered with earth so as to obviate fly and rat breeding.

Salt marshes may be filled by hydraulic dredges, which suck mud and sand from the bottom of an adjacent bay and pump the mud and water mixture through a pipe and discharge it on the marsh. Where harbor or channel improvements are being made by hydraulic dredging very satis-

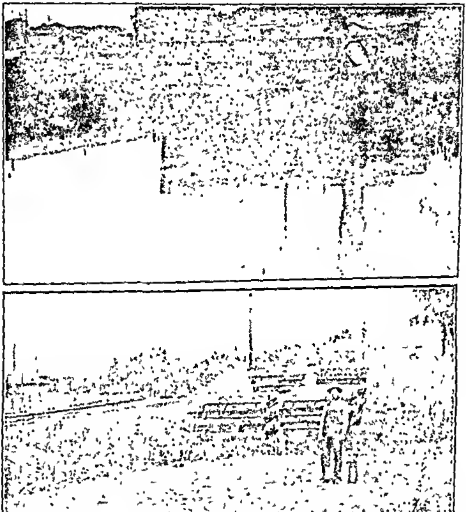

FIG 85.—Upper figure shows a pond adjacent to a railroad and caused by obstructing the natural drainage. A source of many mosquitoes every year. Oiling, while serving the purpose, requires repeated expenditure of time, labor and money. The lower figure shows the same spot after it had been permanently corrected by the railroad company.

factory arrangements may often be made to use the mud and sand at a near-by mosquito-breeding marsh.

When the general land level is at or below the low-water level of an adjacent river or bay, pumping has to be resorted to. Portable pumping units are frequently of much value.

Sundry nuisances.—Water-holding receptacles of many kinds may prove suitable situations for mosquito breeding and must not be overlooked by the "mosquito man." However, it sometimes happens that an overemphasis of the tin can results in attracting the attention away from more important matters, such as dripping hydrants, stagnant ditches, etc. Indeed the water in tin cans unless in shady situations usually becomes too hot for mosquitoes during most of the summer. (Fig. 86.) Heaps of broken gourds commonly reek with mosquito larvae, tubs and barrels of water frequently produce many of these pests, though rather rarely anophelines. Stagnant water in poorly constructed street gutters is often

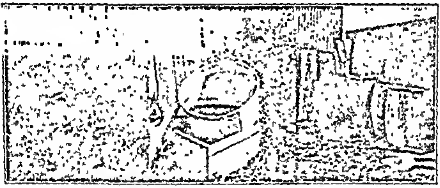

Fig 86 —Tin cans, tubs and barrels in which water may stand and breed mosquitoes

a serious menace. Dripping faucets (Fig 87) may result in pools of water suitable for mosquito breeding.

Oils and larvicides.—All too commonly mosquito abatement and the spraying of kerosene on water are thought of as practically synonymous. While the application of oil to water to kill larvae and pupae has a definite place in mosquito control, all properly conducted mosquito abatement districts look upon oiling as secondary to the primary methods previously discussed. However, because oil may play an important rôle at critical times, specification of types of oil and their proper use should receive careful attention.

Oil for mosquito control must be lethal to larvae and pupae, i.e., a complete kill must be effected; it should have lasting qualities (particularly to trap ovipositing females as long as possible) and must spread well on the surface of the water. Mixtures suitable for larvicidal purposes should have a specific gravity of 31° to 39° Baumé (API) and a viscosity

at least until the matter is further investigated. It is probably sufficient to keep to the windward of the dust clouds and to avoid inhaling the dust as far as possible. In case a great deal of exposure is necessary, one should use some precaution to keep any large amount of Paris green from entering the clothing or accumulating on the skin. The danger to domestic animals through drinking treated water seems very remote. . . . We have never observed any effect of the poison on culicine larvae or on any aquatic insect or animal, however delicate, other than the surface feeding anopheline larvae. In particular, we have not observed any indication of harm to top-feeding minnows or to any other natural enemy of larvae."

Application of oils and larvicides.—Methods of applying oils and larvicides will, of course, depend fundamentally upon the nature of materials used, i.e., whether liquids or dusts, also whether large areas are

FIG. 89.—Showing use of knapsack spray pump in mosquito control

involved or only a catch basin, for example. For relatively small areas or for numerous small and widely separated areas, hand application is most economical and convenient. Where only a few small pools need to be oiled, no doubt pouring on a small quantity of kerosene by hand would suffice.

Hand spraying equipment such as the knapsack spray pump is almost universally used. This type of equipment partly atomizes the oil, resulting in a better spread and a better cover of the water surface, and is at the same time more economical in the use of oil and in labor. Knapsack sprayers c [illegible] capacity, fitted [illegible] ontainer until a strong air pressure is built up. To the outlet pipe, which extends to the bottom of the container, is attached a piece of flexible hose and a

spray nozzle. The spray nozzle is usually attached to the end of a one-quarter-inch metal pipe. (Fig. 88.) In operation the tank is filled about three-quarters full with oil. A hand lever extending over one shoulder when the sprayer is strapped on the back operates the pump plunger. The container should be provided with a lip about one and one-half inches high extending around and above the tip of the can to prevent oil from spilling down the back of the operator. One man with a knapsack sprayer (Fig. 89) can oil about five acres per day of eight hours under open field conditions.

Paris green dusts may be broadcast by hand or by means of a mechanical blower, preferably the rotary type. In either case the dusting should be done with the wind so that the dust floats away from the workman, thus avoiding exposure to the arsenic which may cause a dermatitis.

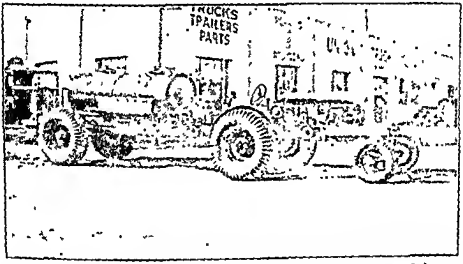

FIG. 90—Tractor equipment used in mosquito control operations in flooded areas (Photograph by Fred L Hayes)

Where anopheline marshes of great area are to be treated, airplane dusting is to be preferred.[11]

Power sprayers are commonly used in mosquito abatement operations. Tractor equipment with special tires as shown in Figure 90 make it possible to carry on operations under exceedingly difficult marsh conditions.

Oiled sawdust may be used to good advantage. The practical use of this material first came to the notice of the writer while on military duty in 1918. A small detachment of troops was camped near an abandoned sawmill and a huge hill of sawdust was available for filling numerous

scale the writer recommends mixing sawdust and ordinary fuel oil in a large pail and broadcasting it by hand where needed. A small winding creek much overgrown with shrubbery and weeds, with steep banks and many pools, was very successfully treated in this manner.

On marshes frequented by wild fowl it is important that heavy oils such as crankcase or crudes should not be used, as these frequently do damage to the birds, apparently by gumming their wing feathers so as to make flight impossible. As a result many water fowl are killed. One of the first objections from duck clubs when oiling is proposed arises from the fear that such heavy oils may be used to the damage and destruction of water fowl.

Oil Drips.—The use of oil drips is well described by Le Prince [12] as follows:

"The use of 'oil drips' for intermittent or continuous application on ditches or streams containing moving water has proved satisfactory. Where the heavy oils are used the drip can is placed 3 to 4 feet above the water surface so that the drops of oil strike the moving water with a blow and at once change into a thin oil film. The stand, base, or object that supports the drip can must be secure and beyond danger of removal by flood waters. Cans of from 5 to 30 gallons' capacity are used for dripping. The drip outlet is placed several inches from the bottom to allow of the settling of the heavier constituents of the oil that might clog up the outlet. The oil being warm in the daytime flows more freely than at night. The object of a dripping stream is to allow a sufficient number of drops of oil to fall on the moving water surface to form a continuous thin film. The water in ditches or streams so treated and kept fairly well cleaned or free from obstructions will convey the oil to all parts of the stream below the drip can and it will keep a film of oil on the places of minimum or zero current. It is in this quiet water that most mosquito larvae are apt to occur.

"On ditches and streams having an average width of water surface of one foot, from 10 to 20 drops of oil per minute are applied. The quantity of oil required depends upon the spread of oil, the alignment of the stream, roughness of banks, grade, obstructions, etc. For economic control a trial should be made at each ditch or stream where a drip can is used to determine the desired rate of flow. The drip can should be regulated accordingly. In many cases the drip need be operated continuously for only one or two days of each week. With larger streams it may be found necessary to operate the drip continuously day and night. On long streams or ditches it is at times necessary to use several drip cans. They are then so located that the next drip can is installed approximately at the point where the effect of the drip at the source disappears. Continuous dry weather may make it necessary to discontinue the use of some drips or to change their location. At such season, pools will be left isolated at the sides of a stream and will have to be filled, or separately treated with oil by other methods. When the stream stops running the use of drips is discontinued and any water left in the stream bed is oiled with a knapsack sprayer or watering pot. With the best care oil drips will clog, due to suspended solids or heavy constituents in the oil, and must be adjusted as often as necessary. The disadvantage of oil drip cans is that they will not give satisfactory service without proper attention, may become clogged, or be washed away by floods. Their

use is generally more effective and economical than the direct application of oil by sprinkler or knapsack sprayer for water in motion. A thinner, but satisfactory, film of oil is obtained from the heavier cheap oils.

"A crude but cheap and easily made drip can consists of a five-gallon can such as is used for shipping illuminating oil. A hole is made in its bottom with a two- or three-inch round nail. A wad of loose cotton is wrapped around the nail just below its head. The nail is then pushed through the hole on the inside of the [illegible]

and the tap adjusted to give within a few drops of the number desired to be [illegible]

Rice culture and mosquitoes.—The introduction of rice culture is often characterized by hasty, haphazard methods, practiced in order to insure quick returns at a minimum expense, with little thought regarding efficiency and future results; sound agricultural practice is disregarded. Haste and carelessness are extremely evident in the construction of the irrigating systems. These for the most part allow liberal seepage and the inevitable result is that the surrounding country is often converted into a veritable bog. In most of the rice districts the entire countryside is dotted with stagnant pools, the roadsides are bordered and in some places actually covered by stagnant water which is, almost without exception, furnishing breeding grounds for myriads of mosquitoes. It is a conservative estimate that more than one-half of the increase of mosquitoes due to rice culture can be traced to such situations that are largely due to neglect and could be wholly corrected.

The breeding of mosquitoes in the seepage and drainage pools outside the rice fields is inexcusable. (Fig. 91.) In the first place, careful and efficient irrigation construction would do away with these pools almost entirely, except where the water has been raised to the surface, and, secondly, those pools that are not eliminated by such construction could easily be cleaned up by draining into a running stream or filling in the depressions that harbor them. All these expedients failing, surface oiling will kill all the larvae that happen to be present. With these secondary pools cleared up, certainly 50 per cent of the mosquitoes of the rice field districts will be eliminated. The water is not turned into the rice fields permanently much before June 1 in California. The mosquitoes of the district, however, have been breeding in other available places since March or some time earlier. Every mosquito destroyed previous to the flooding of the rice field means the cutting off of its countless progeny that would otherwise breed undisturbed in the flooded areas. Again, at the end of the season, the mosquitoes continue to breed for a month or two

after the water is drained off the fields, depositing their eggs in neglected pools. In this way, the adults that overwinter and start the next summer's crop are produced. It seems plain that if an ardent anti-mosquito campaign were waged before and after the water is on the rice fields, the numbers left to start the rice field generations would be greatly reduced.

Although chemical control of rice-field mosquitoes is seldom practiced, oil-soaked sawdust sown broadcast when the rice plants are well grown works no apparent injury to the crop and produces an oil film that kills practically all larvae. Rao and Sweet[13] report that the use of a one-per-cent dilution of Paris green in road dust and wood

FIG. 91.—Showing a rice field with roadside seepage ditch in which mosquitoes breed

ash, in quantities used for larval control, produced no ill effects on the rice or in straw yield. There was no indication that dusting should be stopped during the period in which the paddy was in flower. Among the natural enemies, fish and dragonflies seem to be the most important, but although they undoubtedly exercise some check, they are handicapped by the rice-field conditions to such an extent that their influence may be of little importance.

As has already been mentioned, the malaria-bearing mosquitoes will travel but a short distance, varying with the species, from their breeding places and seldom bite except at night or approaching dusk. Thus it will be seen that malaria prevention demands that those people whose resi-

dence or occupation takes them into the rice country at night or at dusk should depend on personal protection by veils or screened dwellings, in conjunction with careful quinine prophylaxis as a precaution against accidental bites.

Many communities a mile or more away from the nearest rice fields have stoically accepted the mosquitoes that infest their dwellings as a product of the rice fields and calmly ignored the breeding places that abounded on every hand. The observations already made by other observers and confirmed hundreds of times on the northern California mosquito survey are that it would be highly improbable that any of these communities (those a mile or more from the rice fields) would be bothered greatly by mosquitoes of rice-field origin, as they receive their quota of mosquitoes from near-by sources.

When soil conditions are such that fresh water must be continuously added to compensate for loss, an anopheline breeding situation is presented and a public health hazard exists. Under such conditions rice culture contiguous to communities should, no doubt, be prohibited.

Creeks and small streams.—Except for flood water left behind during overflow from floods, great rivers rarely afford opportunity for mosquito breeding. Flood water left behind when rivers recede may be a prolific breeding place of certain species of mosquitoes such as *Aedes vexans* (Meigen) and in some instances a malaria hazard is created in that a breeding place for *Anopheles quadrimaculatus* Say may result from seepage. In many parts of California, as creeks and smaller streams recede during the rainless summer, numerous sunny pools are left behind which soon become green with algae (Spirogyra) among which vast numbers of larvae of *Anopheles pseudopunctipennis* Theobald occur; also pools occur along the banks shaded by wild grapes, willow and other vegetation, in which *Anopheles punctipennis* (Say) find a suitable breeding place. Pools along the banks can frequently be drained off or can at least be thoroughly oiled.

Small streams or creeks that border communities or flow through the town frequently become clogged with rubbish and eventually become prolific mosquito breeders, and situations frequently result which are favorable for Anophelines. Communities should not permit rubbish to be thrown into stream beds. By neatly channelizing such stream beds and planting the banks with shrubbery, an eyesore and mosquito breeder may be rendered attractive and harmless.

Public utilities street vaults.—In practically all urban areas the various public utilities such as telephone, power and light, gas, electric railway, telegraph, and water, have numerous vaults in streets which are frequently the source of a severe local infestation of *Culex pipiens* Linn. during the breeding season. Because of residues, heavy oils

should not be used; instead a cresylic acid base larvicide may be applied at intervals at dilutions of 1 to 10,000.

Sewer inlets and catch basins.—In the newer types of street inlets little opportunity is afforded for water to collect and remain standing for

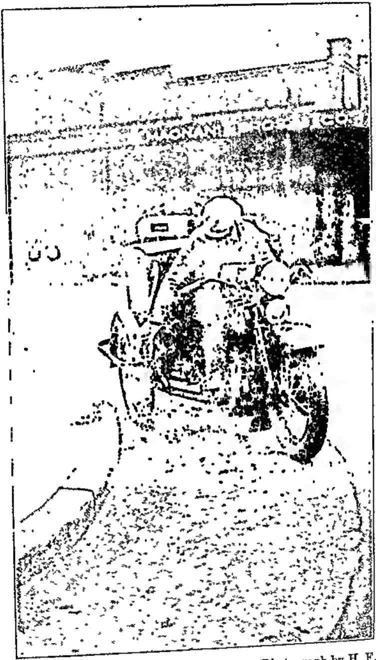

FIG 92.—Motorcycle side car equipped for oiling. (Photograph by H. F. Gray)

mosquito breeding. Most of the old types of inlets and catch basins, especially those connecting to a combined sewer (for domestic sewage and storm water), are apt to produce mosquitoes, particularly *Culex pipiens*

Linn. Oiling is most economically done by means of a motorcycle side-car (Fig. 92). One filling with 25 gallons of oil, with air pressure to 50 pounds per square inch, will suffice for a day's work, i.e., from 200 to 300 catch basins.

Sewage treatment works.—Where mosquito breeding occurs in sewage treatment works, a distillate lightly applied gives satisfactory results and is reported to have no adverse effect on any of the treatment processes.[14] Mosquito breeding seldom occurs in tanks actively in service, although breeding has been reported in the channels of sewage treatment plants where the sewage flow is very slow.

Cesspools, privies, liquid manure pits.—Where pit privies are built in wet areas, water collects and prolific mosquito breeding (*Culex pipiens* Linn.) may result. The use of cresylic acid larvicide is recommended. Where liquid wastes are disposed of in leaching cesspools, mosquito production may be very great if mosquitoes have access to them. Even small knot holes or vent pipes afford a ready means of entrance. If necessary repairs are made the larvicide need not be applied since egress is cut off, otherwise treatment at intervals of about 10 days must be practiced.

Liquid manure pits in connection with greenhouses and plant nurseries commonly produce prodigious numbers of *Culex pipiens* Linn. and *Culex tarsalis* Coq. Oils or larvicides cannot be employed because of danger to plants; however, light applications of pyrethrum extract (in kerosene) at frequent intervals is effective.

Tree holes.—In wooded areas and on estates tree-hole mosquitoes, such as *Aedes varipalpus* (Coq.), cause great annoyance. Tree holes, particularly in oaks, collect water in which the mosquito larvae grow. Liberal application of cresylic acid larvicide is recommended; the larvicide should be applied not only to the water but also liberally swabbed on the wood above the water line to repel egg-laying female mosquitoes. The practice of tree surgery has greatly reduced mosquito breeding in tree holes.

Screening.—Biting habits of mosquitoes differ considerably as already explained, e.g., *Anopheles punctipennis* (Say) is a typical porch biter which points to the necessity for properly screened porches for evening or night use, and *Anopheles quadrimaculatus* Say and *A. maculipennis* Meigen are typically indoor species finding their way inside even though no other opening is left but the chimney. The latter species stick close to their food supply and follow man into his home, hence screened doors opened to admit human beings also admit mosquitoes, and despite good screens malarial infection may nevertheless occur. This fact emphasizes the need of daily destroying the invading anophelines.

The following simple suggestions will prove useful: (1) The best size mesh for all purposes is No. 18, i.e., 18 strands to an inch. (2) Screen

doors should be made to open outward, should fit snugly, should be provided with a strong spring, and a strip of board should be oailed on the lower paoel for the foot to push agaiost when kicking opeo the door. (3) Wiodow screens should screen tbe eotire opeoing and should fit perfectly. (4) Fireplaces should be completely sealed during the mosquito season. (5) Sleeping porches and porcbes used for sitting during the evening must be carefully screened. (6) Vestibuled doors are strongly recommended. (7) Screens must be frequently examined and kept in good repair. (8) Mosquito bars or bed nets usually only afford comfort but not security, since persons are commonly bitteo before retreating beneath them.

Destroy invading anophelines.—The indoor anopheline is usually more to be feared than the ooe in the field. Its opportunity to feed on human blood and consequently to become infected with malaria is largely increased. The daily destruction of all anopheline invaders would certainly reduce the daoger from malaria to a minimum. In carrying on malaria control operatioos at various poiots near Newport News, Va., during the World War the writer emphasized this particularly for camps so situated that the usual mosquito control methods could not be employed Additional precautioos were exercised such as the wearing of head nets, repellents for hands and wrists and a bi-weekly dose of 30 grains of quinine.

Repellents.—Night laborers, watchmen, military pickets, and others compelled to be on duty at oight are, of course, exposed to the bites of mosquitoes aod should exercise some precautioo at least against these pests. Repellents of several kinds have been used with more or less success. The writer has found *oil of citronella* to be one of the most reliable deterrents when simply rubbed on the hands and face; a dozen drops or thereabouts placed in the hollow of the hand and thus applied is generally sufficient.

To this oil may be added various other ingredients; for example, Howard has found the following mixture most effective: 1 ounce of citronella, 1 ounce spirits of camphor, and ½ ounce oil of cedar. Howard found this very satisfactory against *Culex pipiens* Linn. by applying a few drops on a bath towel hung on the head of the bed. He, however, adds that it is oot effective against the yellow-fever mosquito, which begins biting at daybreak when the oil has lost most of its strength.

Other deterrents used and recommended by various authors are: a mixture of castor oil, alcohol, and oil of lavender, equal parts; or a few drops of peppermint or pennyroyal, oil of tar, oil of cassia, or simply pure kerosene.

The following mixture is known as "Bamber Oil" and has been used with fair success by the author: citronella oil (not lemon grass oil) 1½

parts, kerosene (paraffin) 1 part, coconut oil 2 parts. To this mixture 1 *per cent* carbolic acid is added.

Ginsburg [15] reports on a number of tests in which the New Jersey larvicide (pyrethrum-kerosene emulsion) was used as a repellent for adult mosquitoes in limited areas for a short period of time. With the use of various dilutions of the concentrated larvicide (from concentrated up to 1–12), more or less relief was obtained at various outdoor gatherings such as lawn parties, picnics, etc. The results were irregular; in some cases practically complete relief was obtained, in others only partial relief. Apparently some caution is necessary to prevent damage to foliage from the use of too much larvicide. In one case where 5 gallons of concentrate (diluted 1–5) was used on 12,000 square feet area, the lawn grass was injured.

Experiments were conducted in Florida by King, Bradley and McNeel [16] to determine the repellent values of certain materials against *Mansonia perturbans* (Walk.) when sprayed over the vegetation in a limited area. The sprays were applied just before dusk and the results were checked during the following two or three hours. In the presence of a heavy infestation of mosquitoes several of the materials gave a high degree of protection from mosquito annoyance in the center of a sprayed circle one-fifth of an acre in size, when most of the area was covered with a thick stand of dry grass and weeds. After the removal of the vegetation the effectiveness of the sprays was much reduced. The materials that gave a reduction of over 75 per cent in the uncleared, sprayed area were pyrethrum extract, pine-tar oil, oil of citronella and kerosene.

Natural enemies of mosquitoes.—A review and summary of the literature dealing with "Predators of the Culicidae" by Hinman [17] indicates that, excluding fish, the chances of finding satisfactory predators is not very encouraging. Among the natural enemies of mosquitoes few are so frequently referred to as dragonflies (also known as "mosquito hawks"), *bats* and *surface-feeding fish*. *Dragonflies, order Odonata*, are predaceous in both the nymphal and adult stage The aquatic nymphs are commonly found in quiet, shallow, permanent pools suitable also for mosquito breeding, and both may flourish in the same pool in spite of the fact that the dragonfly nymphs, usually relatively few in number, may feed on mosquito wrigglers. Since the nymphs feed in the mud and debris at the bottom, probably few wrigglers are captured. If the wrigglers are easily available, the nymphs will feed on mosquito larvae voraciously. Warren [18] reported a nymph of *Pantala* consuming seventy-five full-grown mosquito larvae by seven o'clock in the evening, which he had placed in a glass half-full of water in the morning. Adult dragonflies are exceedingly adept at capturing mosquitoes on the wing just before and at sunset. However, here again the number of dragonflies, which also feed

oa other insects, is no match for the mosquitoes. Dragonflies do aot fly at night when night-flying mosquitoea are oa the wing.

Bats are insectivorous and feed freely on mosquitoes; as many as 250, it is said, may be captured by one bat in a night, but with many other species of crepuscular and night-flying insects available, bats are aot effective eaough to be a large factor in control, even though one might tolerate them in large numbers near the home. Bat roosts, however, have been established to accommodate bats for tha purpose of mosquito control.

Fish of various species have been advocated for many years. In "Nature" for December, 1891 (pages 223–224), there is this item: "An Englishman living on the Riviera, according to a correspondent, having been troubled by mosquitoes, discovered that they bred in the large tanks kept for the purpose of storing fresh water, which is rather a rare commodity at this Mediterranean resort. He put a pair of carp in each tank and succeeded in this way in extirpating the insect pest."

Howard (1910 loc. cit.) refers to the control of mosquitoes by goldfish in an ornamental aquatic garden near Boston:

> "I took from the pond a small goldfish about three inches long and placed it ia an aquarium where it could, if it would, feed upon mosquito larvae and still be under careful observation. . . . On the first day owing perhaps to being rather easily disturbed in its new quarters, this goldfish ate eleven larvae only in three hours, but the next twenty-three were devoured in one hour; and as the fish became more at home, the 'wigglers' disappeared in short order whenever they were dropped into the water. On one occasioa twenty were eaten in one minute, and forty-eight within five minutes This experiment was frequently repeated and to see if this partiality for insect food was characteristic of those goldfisb only which were indigenous to this locality experimented with, some said to have heen reared in carp ponds near Baltimore, Maryland, were secured The result was the same. . . ."

The most useful of all fishes for this purpose is the top minnow or mosquito fish,[19] *Gambusia affinis* (Baird and Girard), a hardy, rapidly breeding, prolific surface-feeding fish which within its range normally inhabits shallow water suitable for mosquito propagation. It is viviparous and may produce as many as six to eight broods in a seasoa with an average of forty to a brood. The size of the fish ranges from 1¼ inches in length in the male to nearly 2 inches in the female. This fish is easily propagated and adapts itself to n variety of conditions with ease. It has heen introduced into various parts of the world, even over great distances, for example, from Texas to the Hawaiian Islands and thence to the Philippines. Transportation of top minnows can he done satisfactorily in 10-gallon milk cans with tops punched with holes and water kept below the point where the top of the can begins to narrow. Although

as many as 500 fish may be transported for an hour's trip with only moderate loss, not over 200 young fish per can should be shipped on longer trips, and special care must be exercised to remove dead fish at intervals and freshen the water.

For garden pools ten square feet in diameter, twenty top minnows will be ample, and no artificial feeding will be necessary. The *Gambusia* will more or less regulate their own numbers according to the food supply available.

Top minnows will evidently not feed on mosquito larvae when these are motionless, hence are not markedly effective in the control of mosquitoes whose larvae are sluggish, e.g., the usually motionless larvae of *Anopheles quadrimaculatus* Say do not attract the attention of top minnows as readily as do the active larvae of *A. maculipennis* Meig., hence the minnows are not so effective in control.

Other fish which have been found useful are *Heterandria formosa, Fundulus diaphanus* and *Fundulus dispar* for fresh water, and *Cyprinodon variegatus, Fundulus heteroclitus, Fundulus similis, Fundulus majalis* and *Luconia para* for salt or brackish water. To these may be added a number of species as listed by various authors, notably Hegh,[20] Radcliffe [21] and Hamlyn-Harris.[22] The International Health Board of the Rockefeller Foundation has issued (1924) a comprehensive treatise entitled "The use of fish for mosquito control."

In Guayaquil, Ecuador, the yellow-fever-mosquito problem was solved according to Connor [23] by the use of fish. Connor states that the domestic water supply is delivered to the houses daily and is stored in tanks and other receptacles, there being at the time of his writing about 7,000 of the former and 30,000 of the latter, such as barrels, oil cans, earthenware bowls, etc. In these various containers yellow-fever mosquitoes developed in countless numbers. Experimentation with several species of fish finally resulted in the selection of the "*chalaco*" (*Dormitator latifrons*—Family Gobiidae). These fish, furnished to the Yellow-Fever Service by local fishermen, were placed in a specially prepared well, the conditions of which approximated those of the stream from which the fish were taken. After a few days the fish were removed to a second well, the water of which was the same as that used by the city. Connor writes further as follows:

> "The fish are then taken from the wells and placed in tins or pails and delivered to the inspectors Instructions have been given to each inspector that [illegible] public of Guayaquil has responded in a whole-hearted manner to the requests of the Yellow-Fever Service, and many families have in their possession at this

time the identical fish which was given them to mosquito-proof their water container nearly eighteen months ago.

"More than 30,000 water receptacles have in this way been purged of mosquito larvae in a relatively short time and at a minimum of expense. With the continued use of fish it is believed that the yellow-fever mosquito can be reduced to such small numbers that, should a few cases of the disease be introduced into the community, it would not spread."

Fumigants.—Knowing that mosquitoes often hibernate in great swarms in basements of buildings, cellars, and other favorable situations, it becomes necessary to destroy these in order to prevent them from propagating in the spring of the year. A number of very satisfactory fumigating agents may be mentioned, such as pyrethrum powder, sulphur dioxide, fumes of cresyl, pyrofume (a turpentine by-product), and Jimson weed fumes. The use of powdered Jimson weed (*Datura stramonium*) is recommended at the rate of 8 ounces per 1,000 cubic feet of space, mixing it with one-third its weight of saltpeter to facilitate combustion. The mixture should be spread on a tin pan or stone and ignited at several points The fumes are not dangerous to human life.

Mosquito bites.—Mosquito bites, while perhaps never serious in themselves, may lead to blood poisoning through scratching with the fingernails in the attempt to relieve the irritation which is often intense. To relieve this irritation any one of the following may bs applied, viz.: ammonia, glycerin, alcohol or iodine. According to Howard ths most satisfactory remedy known to him is the application of moist toilet soap He also mentions touching the puncture with a lump of indigo as affording instant relief, or touching the parts with naphthaline moth balls.

Mosquito control and wild life conservation.—Mosquito abatement operations if intelligently conducted need not be detrimental to wild life, though no doubt they bave been so at times. In conducting control operations in suburban and rural areas an understanding of wild life ecology is urged, and a modification of measures to suit the situation is necessary. It is regrettable if wild life has been harmed; but there have also been unfounded complaints on the part of misinformed and intolerant wild life conservationists which have made it distinctly difficult for mosquito abatement officials to perform their proper function. It is important that the seemingly divergent viewpoints of conservationists, duck clubs and mosquito abatement officials be harmonized. No doubt each group will need to make reasonable concessions.

Coöperation between responsible mosquito abatement officials and the representatives of wild life interests is only made difficult when one side or the other sets itself upon a pedestal. Our properly trained experts in mosquito control are just as truly biologists as are wild life authorities, the only difference is usually in the fact that the former are trained in the field of invertebrate zoölogy and the latter in the field of verte-

brate zoölogy. Both should be ecologists and have training in limnology. Fortunately, most of our authorities in the field of mosquito control have had training not only in the ecology of aquatic invertebrates but for obvious reasons also in vertebrate ecology. Entomologists trained in mosquito control and ecology, and wild life conservationists equally well trained in ecology ought to be able to see "eye to eye" as biologists. Working thus together as biologists on an equal footing, the aims and objectives of both sides will be advanced.

Duck clubs.—In most states the duck-shooting season does not begin until November first or later. By that time cold weather usually stops mosquito breeding. However, many duck clubs start flooding their duck ponds long before this, perhaps to have the ponds ready to attract the earlier migrants. These slowly filled shallow ponds may prove to be a mosquito menace. Some clubs keep their ponds well flooded throughout the year, and if the banks are steep and top minnows have access to all parts of the pond, there is no mosquito problem The ponds which are most difficult to handle are those that are drained off in January or February after the duck season is over, and are allowed to remain dry during the summer, being again flooded in late summer or early autumn while the weather is still warm. Breeding is sure to occur. *Aedes* eggs, such as *Aedes dorsalis* (Meig.) from preceding years, promptly hatch, and a plague of mosquitoes soon appears.

Neff (1935), of the U. S. Bureau of Biological Survey, states in the Proceedings of the Sixth Annual Meeting of Mosquito Abatement Officials in California, p. 16, "Impounding of water, or the maintenance of a constant water level by means of tide gates that permit an equalized flow of water through the salt marshes, seems to be the method of control which has aroused little or no adverse comment from biologists. This method also offers opportunity for experimental work on planting of better wild life food plants than may formerly have existed on the areas with fluctuating water levels"

Although expensive where a larvicide becomes necessary, pyrethrum should be used instead of oil Neff (loc. cit.) states that pyrethrum larvicide has "no known deleterious effect upon wild life."

The following rules in dealing with mosquito control in connection with duck clubs are suggested:

1. Continuous all-year flooding of ponds is permissible and approved, provided the ponds are stocked with "mosquito fish" at all times

2. Intermittent maintenance of ponds is permissible, provided, (a) the water is effectively removed early in the spring before breeding occurs, and (b) the water is not put in in the autumn until the weather is cool enough to prevent mosquito breeding

3. Ponds must have sound, tight banks and bottoms to prevent wet areas due to seepage.

4. Poads must have sufficient depth througbout to permit mosquito fish to penetrate frecly all parts.

5. Poads must not be avergrown with vegctation, especially along and near the margins, so tbat "mosquito fish" may have free acccss to all parts.

6. If the water is pumped, the supply and equipment should be adequate to fill the poads with reasonable speed.

7. Duly authorized inspectors of mosquito abatement districts ia which the ponds occur sbould he permitted to inspect tbe area frequently to determine whether or not mosquito breeding is occurring.

8. If in spite af all precautions mosquito larvae do occur, a larvicide, preferably a pyretbrum emulsion, should be applied, but only where breeding is actually in progress.

Impounded water.—As pointed out in an earlicr chapter (Chapter XI), impounded waters may afford excellent breeding places for *Anopheles quadrimaculatus* Say within its range if flotage gathers on the surface. Reservoirs for domestic water supply formed in river canyons with steep-sided, rocky walls and floor are aeldom a menace, and in addition such reservoir sites are almost invariably stripped of all vegetation so that flotage is reduced to a minimum. Wherever rivers with comparatively flat grades flow through a terrain of low relief, reservoirs for power or navigation are commonly not stripped and abouad ia flotage, thus formiag a good breeding place for *A. quadrimaculatus* Say. To minimize the danger from mosquito production Paris greea or larvicide must be applied. Power launches with power sprayiag or dusting equipment are well adapted for large areas of impounded water. Airplane dusting would appear to he economical for large open areas, hut according to Watson [24] (1936) a tortuous shoreliae presenting vegetatioa does not offer a suitable condition for airplane dusting for *A. quadrimaculatus* Say control, and is hazardous. In his experimental work Watson used Paris green and powdered soapstoae, the Paris green component varying from 11 to 12.5 per eent by volume. It was required that the Paris green used should contain at least 50 per cent available arsenious oxide aad that 95 per eent should pass a 300-mesh holting cloth. The dust was mixed in a large concrete mixer, and the proportion of Paris green to soapstone in the mixture checked by chemical analysis. A reduction of 98 pcr cent in the densely vegetated swamp land was effected and 94 per cent in the open lake region.

Algicides.—Under some types of shallow water conditions the growth of various types of algae (green alimes or moss) becomes so dense that not only are the activities of fish impaired, but applications of oil become ineffective or only partly effective. When this is found to be the case, it is advisable to apply an algicide such as copper sulphate, to kill off the organic growths. The dosage required to kill the types of organisms which give the "mosquito man" trouble is about three pounds per million

TABLE III

SHOWING DEATHS FROM MALARIA IN HAVANA FROM 1871 TO 1911 INCLUSIVE

The enormous reduction in deaths will be seen to begin with the inauguration of anti-mosquito measures in 1901.

YEARS	TOTAL DEATHS	DEATH RATE	YEARS	TOTAL DEATHS	DEATH RATE
1871	262	1.33	1892	286	1.33
1872	316	1.60	1893	246	1.12
1873	329	1.61	1894	201	0.90
1874	288	1.45	1895	206	0.90
1875	284	1.43	1896	450	1.95
1876	334	1.68	1897	811	3.48
1877	422	2.12	1898	1907	8.00
1878	453	2.28	1899	909	3.76
1879	343	1.72	1900	325	1.30
1880	381	1.93	1901	151	0.55
1881	251	1.26	1902	77	0.29
1882	223	1.12	1903	51	0.19
1883	183	0.91	1904	44	0.16
1884	196	0.98	1905	32	0.11
1885	101	0.50	1906	26	0.08
1886	135	0.67	1907	23	0.08
1887	269	1.34	1908	19	0.06
1888	208	0.99	1909	6	0.01
1889	228	1.11	1910	15	0.05
1890	256	1.23	1911	12	0.03
1891	292	1.37			

TABLE IV

Showing the diminishing malaria death rate (per 100,000 population) for California for the years 1906 to 1937 (incl). The first anti-anopheline measures in this state were put into effect during the summer of 1910 in a small malarial section of Placer County and largely expanded to include other foci in other parts of the state during the following years (The rates since the latest census are subject to correction)

YEAR	DEATHS	DEATH RATE	YEAR	DEATHS	DEATH RATE
1906	111	5.9	1922	31	0.78
1907	70	3.5	1923	32	0.76
1908	80	3.6	1924	24	0.51
1909	112	4.9	1925	29	0.63
1910	113	4.7	1926	9	0.19
1911	121	4.8	1927	15	0.30
1912	101	3.9	1928	17	0.32
1913	77	2.8	1929	10	0.29
1914	70	2.5	1930	12	0.21
1915	45	1.5	1931	7	0.12
1916	54	1.8	1932	5	0.08
1917	47	1.5	1933	3	0.05
1918	55	1.7	1934	5	0.07
1919	28	0.8	1935	6	0.08
1920	34	0.90	1936	6	0.08
1921	43	1.14	1937	10	0.13

gallons of water. Dosages larger than three pounds per million gallons may kill trout and less resistant species of fish and should be avoided in ponds containing fish.

In moderate-sized pools the copper sulphate crystals may simply be hand cast. In larger bodies of water the copper sulphate is best applied by placing it in sacks and dragging it, especially along the shallow areas, until dissolved. Usually several applications during a season will be required.

Malaria reduction as the result of anti-mosquito measures is well shown by Tables III (after Cassa [25]) and IV on page 259.

Results obtained in combating yellow-fever mosquitoes.—The table taken from Doane [26] shows the death rate in Havana due to yellow fever from the years 1893 to 1902 inclusive; the work of the Yellow Fever Commission based on mosquito control having been put into effect in 1901 and 1902. Surely this table (Table V) is eloquent in its praise of this splendid work.

TABLE V

DEATHS IN HAVANA FROM YELLOW FEVER DURING YEARS 1893 TO 1902 INCLUSIVE

	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902
January	15	7	15	10	69	7	1	8	7	0
February	6	4	4	7	24	1	0	9	5	0
March	4	2	2	3	30	2	1	4	1	0
April	8	4	6	14	71	1	2	0	0	0
May	23	16	10	27	88	4	0	2	0	0
June	69	31	16	46	174	3	1	8	0	0
July	118	77	88	116	168	16	2	30	1	0
August	100	73	120	262	102	16	13	49	2	0
September	68	76	135	166	56	34	18	52	2	0
October	46	40	102	240	42	26	25	74	0	0
November	28	23	35	244	26	13	18	54	0	0
December	11	29	20	147	8	13	22	20	0	0

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Students concerned with the Tabanidae are referred to such monographic works as Osten Sacken,[1] Hine,[2] Enderlein,[3] Kröber [4] and others.

Breeding habits and life history.—The eggs are deposited during the warmer months of the year in favorable situations on objects such as leaves of willow and aquatic vegetation, usually overhanging swampy areas, ponds, etc. (Fig. 95). The incubation period is greatly influenced by weather conditions, but during midsummer the usual range is from five to seven days. The larvae fall to the surface of the water, upon mud or moist earth, in clumps and quickly drop to the bottom or burrow into the wet or damp earth where they begin feeding on organic matter. Some species are predators, sucking the juices of insect larvae, crustacea, snails, earthworms and other soft-bodied animals; cannibalism has been observed in several species. The larvae of Tabanidae are commonly encountered buried in the mud along the edges of marshy ponds, roadside ditches, the overflow from rice fields, and the writer has found numerous larvae of *Tabanus gilanus* Townsend in the mud at the edge of salt marshes. The larvae of certain species may be found in moist leaf mould and debris.

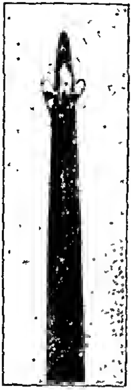

Fig 95.—A deer fly (Chrysops) in the act of oviposition. Note also an egg mass farther down on the leaf. (Photo by Hine.) × 1.

The larvae grow rapidly during the rest of the summer and autumn, and very slowly if at all during the winter in the single-brooded species, attaining full growth in the early spring. The number of larval instars seems to be uncertain, varying according to some authors from four to nine, the first molt evidently taking place shortly after hatching. An excellent account of the early stages of Tabanidae may be found in the work of Marchand.[5]

When the full-grown larva prepares to pupate, it moves into drier earth usually an inch or two below the surface, and in a day or two the pupal stage is reached. This stage requires from two to three weeks, varying with the species. Stone[6] reports that most of the *Chrysops* species emerge in less than two weeks, even in as short a time as five days. The flies emerge from the pupa at the surface and the wings soon unfold and the insects take refuge among nearby foliage or rest on objects near at hand and shortly begin feeding, the females seeking blood and the males feeding on flowers and vegetable juices where one may find them by sweeping with a net.

Much important information based on rearing experience with many species may be obtained by consulting the various publications by

Schwardt.[7] In an earlier paper (Research paper 219, Journal Series, Univ. of Arkansas) Schwardt reports life-history records based on 202 individuals of *Tabanus lineola* Fabr., a common North American species of "greenhead," viz., average incubation period four days, average larval period 48.8 days, average pupal period 8.1 days, pre-oviposition period average nine days, total developmental period averaging 96.9 days.

In the Sierra Nevada and other mountain ranges horseflies breed in great numbers at elevations of 8,000 to 9,000 feet in soggy ground caused by springs and water from melting snow in the summer. Deer and other wild animals suffer much from the bites of these flies.

Bites.—The horseflies have broad bladelike mouth parts (Fig. 25) by means of which a deep wound may be cut, causing a considerable flow of blood. The bite is painful and owing to the intermittent biting habits of the flies there is great danger from infection. "Webb and Wells,[8] working on *T. phaenops* O.S. in western Nevada, estimated that eight flies feeding to satiety would consume a cubic centimeter of blood. On this basis they calculated that 20 to 30 flies feeding for six hours would take an average of at least 100 cc. of blood. This would amount to approximately a quart in ten days. Philip,[9] working in Minnesota, derived a larger estimate of blood loss. Basing his figures on a somewhat heavier infestation than that in Nevada, Philip placed the daily loss of blood for each animal at 300 cc., or nearly one-third of a quart. Neither of the estimates includes the blood which exudes from the bite after the fly leaves. Philip, however, calls attention to this additional loss. The horseflies most abundant in Arkansas are comparable in size to the species on which these estimates of blood loss were made, and the infestation is often heavier than 50 flies per animal." (Schwardt, 1936, loc. cit.)

In describing an outbreak of gadflies in Kentucky, Garman has the following to say:[10]

> "Beef cattle had lost an average of 100 pounds as a result of the constant annoyance from them. . . . On cattle I counted from ten to nineteen. On mules and horses in harness they were a constant annoyance and even hogs were not exempt. Seven of the flies were counted on the exposed side of one of these animals lying in a puddle [illegible]

Relation to anthrax.—Anthrax, also known as malignant pustule or carbuncle, wool sorter's disease, charbon (French), is caused by *Bacillus*

trypanosomes in the flies a further experiment was conducted, in which seventy-four flies, hatched from eggs of a fly which had previous to egg deposition fed on a surra-infected monkey, were allowed to bite a healthy monkey during a period of two weeks with negative results.

Mayne concludes that the "contaminated labellum of the fly does not appear to be a factor in the conveyance of infection. The maximum length of time that *Trypanosoma evansi* (Steel) has been demonstrated microscopically in the gut of this species of fly after feeding on infected blood is thirty hours; the organisms were found in the fly's dejecta two and one-half hours after biting the infected animal; and suspensions of flies, when injected subcutaneously, were found infective for animals for a period of ten hours after the flies had fed on infected blood."

In a letter to the writer under date of November 18, 1913, Mayne states that "infection is not transferred by *Tabanus striatus* Fabr. later than twenty minutes after the infective meal. The longest time I have succeeded in inducing flies to transmit was fifteen minutes and all results from twenty minutes to forty-eight hours were entirely negative. This despite the fact that trypanosomes survive in the intestinal tract of *T. striatus* Fabr. for a period of thirty hours." He believes this horsefly to be the principal carrier of surra and that the stable fly, *Stomoxys calcitrans* (Linn.), is ruled out, which is indeed indicated by the long and careful series of experiments conducted by that worker on both species of flies

Tularaemia.—In 1919 a disease of hitherto unknown etiology was reported by Francis [13] as deer fly fever or Pahvant Valley plague. It is later described by the same author [14] and given the name tularaemia. It is a specific infectious disease traceable to *Pasteurella* (=*Bacterium*) *tularensis* (McCoy and Chapin) Francis. It was originally described as a disease of rural populations occurring during the summer months, coinciding with the prevalence of the vector, *Chrysops discalis* Will. Francis states, "Following the fly bite on some exposed surface of the body (neck, face, hands or legs) the onset is sudden, with pains and fever; the patient is prostrated and is confined to bed; the lymph glands which drain the bitten area become tender, inflamed and swollen, and commonly suppurate, requiring incision. The fever is of a septic type, lasting from three to six weeks, and convalescence is slow." The pathology of tularaemia is described in great detail by Lillie and Francis in Bulletin 167 (1936) National Institute of Health. Francis and his co-workers found that jack rabbits constitute an important reservoir for the infection and that the infection is transmitted from rabbit to rabbit by the horsefly. The fly is undoubtedly merely a mechanical vector of the disease as indicated by the experiments of Francis and Mayne, et al. (loc. cit.). It has also been found that tularaemia is carried from rabbit to rabbit by means of the rabbit louse, *Haemodipsus ventricosus* (Denny). *Cimex lectularius*

Linn., the common bedbug, was also found to be a successful carrier in experiments with guinea pigs, as was the mouse louse, *Polyplax serratus* (Burm.), in the case of white mice. Mosquitoes and fleas have also been shown to be suitable vectors. The spotted fever tick, *Dermacentor andersoni* Stiles, is also a vector, perhaps the most important, because the infection is conveyed through the eggs to the larvae, Tularaemia is now known to exist in nature in many other animals, among these meadow mice, ground squirrels, coyotes, sheep, and quail.

Filariasis.—The so-called mango fly, *Chrysops dimidiata* v. d. Wulp, has been shown by Leiper (loc. cit.) to be a vector of *Loa loa* (Cobbold) in various endemic regions in Africa, particularly the Belgian Congo. *Chrysops silacea* Austen has been proved to be a carrier of the organism by Connall and Connall [15] who completely elucidated the life cycle not only in this fly, but also in *C. dimidiata* v. d. Wulp. Microfilariae of *Loa loa* are found in the peripheral blood vessels during the daytime, showing a diurnal periodicity which gave rise to the term *Microfilaria diurna* Manson. The larvae measure about 300μ in length by 7.5 in thickness, resembling *Wuchereria bancrofti* (Cobbold) quite closely. In this stage they are ingested by the *Chrysops* flies and undergo development similar to that of *Wuchereria bancrofti* in the mosquito Metamorphosis is completed in from ten to twelve days, increasing in length "tenfold." When the infected fly bites, the mature larvae issue from the proboscis, come to lie upon the skin of the host and quickly disappear by burrowing.

The adult worms, females measuring from 50 to 70 mm. in length and the males about half this length, inhabit the superficial subcutaneous connective tissue and are known to move about from place to place quite rapidly, giving rise to transient itching swellings known as Calabar swellings. The parasites have been observed in many parts of the body, such as the scrotum, penis, breast, eyelid, tongue, finger and back.

El debab.—El debab is a trypanosomiasis of Algerian horses and camels traceable to *Trypanosoma berberum* Edmond and Et. Sergent. This disease is evidently spread by horseflies, *Tabanus nemoralis* Meig. and *T. tomentosus* Macq., being considered the vectors.

Control.—Inasmuch as the painful bite of the Tabanidae, especially if these insects are abundant, makes the life of domesticated animals, notably horses, quite unbearable, it is desirable that some repellent substance or mechanical means be employed to prevent injury. Efficient repellents usually contain fish oil, which is disagreeable and in the presence of dust produces a filthy coat; other materials in use are "dips" and these do not as a rule act for more than a few hours at most. Furthermore, where whole herds of animals are to be treated, this method is impracticable. Horse nets afford considerable relief, and often avert dangerous "runaways"

Comparatively little of a preventive nature has beeen done, except for the notable work of Porchinski, reported by Howard.[16] Porchinski observed that tabanids collect in great numbers in the neighborhood of damp places and lower themselves to the surface of pools to drink, actually touching the water with their bodies. It occurred to him that a covering of kerosene on the water would endanger the lives of the insects as they came in contact with the surface. Hence a quantity of kerosene was applied to a given pool, with most gratifying results. By the third day of the experiment, the "pool of death" was covered with "floating islands" of dead tabanids. Porchinski recommends that a favorite pool be selected, and that the oil be poured on so that a thick uniform layer of oil is formed covering the entire pool. Such "pools of death" apparently attract the tabanids from over a considerable adjacent area. The oil must of course be applied as early as possible during the season when the adult flies appear and begin to mate and deposit eggs.

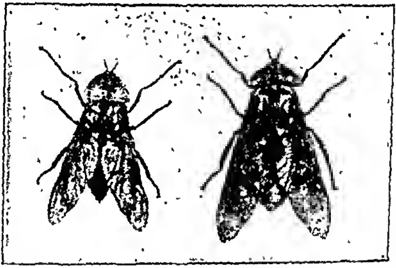

FIG 96.—The black horsefly (*Tabanus atratus*), male at left, female at right. × 1.5. (Photo by Hine.)

The author [17] has called attention to the breeding of tabanid flies in rice fields, particularly in roadside pools, the result of rice field drainage. Correction of drainage defects is an important procedure. In the California rice fields the author found characteristic egg masses of *Tabanus punctifer* O.S. attached to the stems and blades of rice plants. These eggs were commonly heavily parasitized by the hymenopterous egg parasite, *Phanurus emersoni* Girault. This parasite has been shown by Parman [18] to be a potent factor in the control of tabanids near Uvalde, Texas, where artificial dissemination of the parasite was practiced.

genus *Tabanus* alone. They are world-wide in distribution. Only a few of our common species are mentioned here.

(1) *Tabanus atratus* Fabricius, the black horsefly (Fig. 96), measures from 16–28 mm. in length. It is distributed over most of the United States east of the Rocky Mountains and into Mexico. The whole insect is uniformly black and the thorax and abdomen in well-preserved specimens are thinly covered with a whitish dust which is easily rubbed off when the specimens are not cared for properly.

(2) *Tabanus stygius* Say is the black and white horsefly and is a widely distributed species east of the Rocky Mountains. Length 20–22 mm. *Third segment of the antennae red at base, blackish at apex, first*

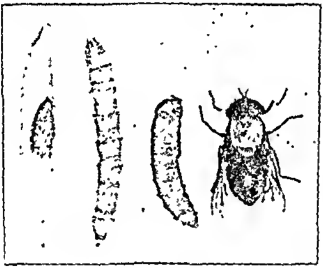

FIG 97—*Tabanus punctifer* Egg mass on willow leaf, larva, pupa and adult female fly

and second segments and palpi dark; legs black, often the tibia are reddish at the base, wings yellowish brown with posterior border approaching hyaline, a brown spot on the bifurcation of the third vein, also the transverse vein closing the discal cell margined with brown; abdomen a uniform black; in the female the thorax dorsally is plainly whitish pollinose with more intense longitudinal lines, the thorax of the male is dorsally a uniform grayish brown.

(3) *Tabanus punctifer* O.S is also a black and white horsefly (Fig. 97) resembling *T stygius* Say except that the front tibiae are white on the basal third and the thorax is uniformly white in both sexes, there is usually a small dark spot near the tip of the wing. It is the largest and best known species of horsefly in western North America, particularly along the Pacific coast.

(4) *Tabanus vicarius* Walker (*Tabanus costalis* Wied.), the greenhead, is one of the most dreaded stock pests common throughout the South.

"Length 12–14 mm. Palpi yellowish, antennae brownish with the annulate portion darker; thorax including the scutellum uniformly grayish-yellow pollinose; legs largely black, base of front tibiae and the middle and hind tibiae except at apex yellowish; wings hyaline with the costal cells yellowish, veins yellowish; abdomen above alternately striped with black and grayish yellow. In the female the frontal callosity black above, with a very much narrowed prolongation, the part of which adjacent to the callosity is sometimes obliterated, leaving the upper part as a separate spot. The male is much like the female and easily associated with it, but there is a tendency toward obliteration of the distinct markings of the abdomen, the black of the female is replaced by brownish and the stripes may blend so that the whole base of the abdomen is practically one color." (Hine.[19])

(5) *Tabanus lineola* Fabr., the lined horsefly, is also an important stock pest widely distributed in eastern, central and southern North America.

"Length 12–15 mm. Palpi white; antennae reddish, annulate portion of third segment darker; thorax brown and gray striped, the latter color not prominent; wings hyaline; legs reddish, apex of the front tibia plainly, apexes of middle and hind tibiae faintly, and all of the tarsi dark brown; abdomen above brown or black with three prominent, gray stripes. The males and females of this species are easily associated. In the latter sex there is sometimes a confusion of colors; the dark is replaced by reddish but the gray mid-dorsal stripe is always prominent in all well-preserved specimens" (Hine.)

(6) *Tabanus sulcifrons* Macq. is known as the autumn horsefly.

"Length 18–21 mm. Palpi brownish, antennae nearly black with the third segment brownish at base; legs dark, bases of tibiae darker; wings with a distinct brownish tinge, cross veins at the end of the discal cell and bifurcation of the third vein margined with brown. Female front with parallel sides, frontal callosity shining brown, not quite as wide at the front, nearly square and with a linear prolongation above. Segments of the abdomen above with prominent gray, hind margins which expand into large gray triangles in the middle; usually a black mark on the anterior part of each of the second and third segments at the apex of the gray triangle. In the males the division between the large and small facets of the eye prominent; head slightly more convex than in the female but nearly of the same size, coloration of the whole body the same as in the female." (Hine.)

(7) *Tabanus striatus* Fabr. is said to be the most prevalent horsefly of the Philippine Islands, and is known to be an important carrier of surra. The following description is after Mayne (loc. cit.).

"The male is very distinct from the female, being smaller and having a larger head and different color markings. Size: 14 to 15 millimeters. Wing expanse:

25 to 28 millimeters. The distinctly clavate palpi are shorter than in the female, only two-thirds as long as the labium; they are dirty white and fringed with

yellow. The area of the large facets of the eye is colored Roman sepia sur-

ts has a

color is

7 milli-

derably

is alternately striped with Cologne earth and pale clay yellow. The median *stripe is pale clay yellow. In both sexes the thorax is indistinctly* striped with pale clay yellow and pale brown, and the wings are transparent except the costal and subcostal cells, which are pale brown."

(8) *Chrysops callido* O.S. is a widely distributed species, measuring from 7 to 9 mm., and is black in color with large pale yellow spots on the sides near the base of the abdomen.

(9) *Chrysops celer* O.S. is black in color, the female with dense orange pile on the pleurae. It measures from 8 to 11 mm. in length. It appears to have a more northerly distribution.

(10) *Chrysops discalis* Williston is gray to yellow-gray in the female with black spots on the abdomen, in the wing picture the hyaline discal cell and spot at the bifurcation of vein R_{4+5} are quite characteristic. In the male the color is predominately black with yellow-gray spots on the abdomen. Length 8 to 10.5 mm. It is reported from Utah, Nevada, California, Oregon, Washington, Nebraska, North Dakota, Wyoming, Montana, Colorado, also Manitoba, Saskatchewan.

(11) *Chrysops dimidiata* v. d. Wulp is a southwest African species measuring 8.5 mm. in length. The face is dusty brownish yellow, the thorax is piceous and the abdomen is reddish ochraceous with a fulvous pilosity.

Key to the Tabanid Genera of Nearctic America

(Arranged by T. H. G. Aitken after Brennan [20] and Stone [21]
Refer also to Surcouf.[22])

1. Hind tibiae with apical spurs; ocelli usually present .... Subfam. Pangoniinae (2)
   Hind tibiae without apical spurs, ocelli usually absent, if present rudimentary .... Subfam. Tabaninae (9)
2. Flagellum of antenna composed of eight annuli .... (3)
   Flagellum with five distinct annuli .... (7)
3. Second anal vein sinuous .... *Bequaertomyia* Brennan 1935
   Second anal vein not sinuous .... (4)

4. Eyes of female acutely angulate above; wings darkened anteriorly. *Goniops* Aldrich 1892
   Eyes of female rounded (normal); wings of uniform color.......... (5)
5. Palpi short, stubby, about equal in length to proboscis which is conspicuously shorter than head............*Apatolestes* Williston 1885
   Palpi slender, distinctly shorter than proboscis which is often as long as or longer than head .... (6)
6. Cell R_5 petiolate ....*Esenbeckia* Rondani 1864
   Cell R_5 open ....*Stonemyia* Brennan 1935
7. (2) Pedicel of antenna about half as long as scape. .*Silvius* Meigen 1820
   Pedicel of antenna more than half as long as scape, often nearly as long. (8)
8. Wings evenly infuscated; abdomen globose, much wider than thorax; antennae very slender and elongate; stump at bifurcation of vein R_{4+5}. *Neochrysops* Walton 1918
   Wings irregularly infuscated, exhibiting a variety of patterns (entirely hyaline in *C. hyalina* Shannon); abdomen normal; antennae variable; bifurcation of vein R_{4+5} without stump (rarely appearing adventitiously) ....*Chrysops* Meigen 1803
9. (1) Scape of antenna considerably longer than thick; frons of female widened below, broader than high, with a velvety-black spot to each side at angle made by eye and subcallus*; flagellum of antenna with four annuli; wing gray, with small white maculations. *Haematopota* Meigen 1803
   Scape of antenna usually scarcely longer than thick; frons of female not broader than high, without velvety-black spots; flagellum of antenna usually with five annuli; wing pattern, if any, otherwise..... (10)
10. Eye bare; subcallus very swollen and shiny; genae denuded; dorsal angle of flagellum small and blunt; wing at least partially infuscated.. (11)
    Without above combination of characters; if the subcallus is enlarged and denuded, the eye is densely pilose.......................... (12)
11. Scape of antenna swollen, at least below; apical half of vein R_4 turned [illegible]
    forward; apex of wing not hyaline; tibiae not swollen. *Whitneyomyia* Bequaert 1933
12. (10) Flagellum of antenna with no dorsal angle; frons of female very narrow, the median callus a very slender line; no ocellar tubercle; wing with at least a subapical brown spot; eye bare. *Diachlorus* Osten Sacken 1876
    Not with this combination of characters.......................... (13)
13. Basal portion of antennal flagellum with a prominent, forward-projecting tooth reaching nearly to base of annulate portion; eye pilose. *Dicladocera* Lutz 1909
    Basal portion of antennal flagellum with or without a prominent dorsal angle, but if this is produced forward the eye is bare...... .... (14)
14. Basal callus in female lacking or very much reduced, separated from eye by a considerable space; neither palpus black nor abdomen with a narrow dorsal stripe .... (15)

* That part of the frons below the level of the lower, inner angle of the eye and [illegible] is proper (just dorsad) usually [illegible] gin, the *basal callus*, and the [illegible] joined to the *basal callus*.

Basal callus in female as wide, or nearly as wide, as frons, or, if narrowed, still considerably wider than median callus; either palpus black or abdomen with a narrow dorsal stripe........................ (17)

15. Eye distinctly pilose; no distinct ocellar tubercle (eye of female usually with a single, diagonal, purple line which often shows even in dried specimens) .... *Atylotus* Osten Sacken 1876

Eye bare or very sparsely pilose; ocellar tubercle present or absent (frons of female about five times as high as width at base).......... (16)

16. Basal callus a swelling at base of a slender raised ridge; a distinct ocellar tubercle present in female; abdomen brownish, with white bands, the apex compressed................ *Leucotabanus* Lutz 1913

No basal or median calli or ocellar tubercle present; bright green or yellow species, the abdomen not distinctly compressed apically. *Chlorotabanus* Lutz 1909

17. (14) Annulate portion of antennal flagellum hairy; no ocellar tubercle; second palpal segment short and stout, with erect hair; proboscis short. *Anacimas* Enderlein 1923

Not agreeing entirely with above, the hair of antennal flagellum very inconspicuous if present.................... .... (18)

18 Rather small, species with bare or sparsely pilose eye, scarcely any angle, and no dorsal excision on flagellum of antenna, and frequently a stump vein from vein R_4..................*Stenotabanus* Lutz 1913

Eye bare or pilose, but if a stump vein from vein R_4 is present either the dorsal angle of the antennal flagellum is distinct or the eye is densely pilose, or both ....*Tabanus* Linné 1758

B. Snipe Flies

Family Rhagionidae (Leptidae)

Snipe flies belong to the dipterous family Rhagionidae formerly known as Leptidae. Several members of the family are bloodsucking Leonard[23] characterizes the family as follows:

> "Flies of moderate to large size usually more or less elongate and nearly bare to moderately pilose, rarely rather densely hairy, never, however, with distinct bristles Males usually holoptic; more rarely dichoptic. Empodium pulvilliform, there being three pads of about equal size between the tarsal claws [illegible] referred [illegible] able: (a) [illegible] ber; (b) the segments not more than eight in number; more closely applied, without style or arista; (c) fewer in number with a differentiated segmented style or arista, altogether not more than eight; (d) [illegible] without a dorsal or terminal arista Veins [illegible] anteriorly; third longitudinal cell furcate; [illegible] usually present."

The genus *Symphoromyia*[24] "includes leptid flies with five posterior cells, the anal cell open; third antennal joint simple, rather deep vertically, attached above its middle usually kidney-shaped (sometimes con-

cave in profile below the arista, then not quite kidaey-shaped); arista subapical; tibial spurs none in front, two in the middle, one bebiad, but often quite weak in males." The females of several species are vicious biters, behaving somewhat as do the tabanid flies beloaging to tbe genus *Chrysops*. They alight on the exposed parts of the body quite silently and singly and inflict a suddea painful bite usually before their preseace is known. Among the severe biters are *Symphoromyia atripes* Bigot, a western species measuriag 5.3 to 8 mm. in leagth, black, with reddish legs; *S. pachyceras* Williston, particularly a Pacific coast species, measuring 6 to 9 mm. in length, wholly black except narrowly on tbe knees, the inner proboscis aad stems of the halteres which are yellow; *S. kincaidi* Aldrich, pile of the thorax and head black, of abdomen largely yellow, front and middle knees narrowly red, a Pacific coast species. *S. hirta* Johns. is shown in Figure 98.

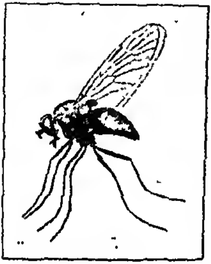

FIG 98.—A snipe fly, *Symphoromyia hirta*. (Adapted after Hearle)

The mouth parts of *Symphoromyia* evidently vary considerably. The *biting* forms have a prominent stout retractile labial sheath which closely ensheaths the functional chitiaized piercing structures.

Practically nothing is known about the breeding habits aad life history of the species of *Symphoromyia*. The rhagionids as a group are known to breed in moist soil, where there is decaying vegetation; the larvae are predaceous.

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CHAPTER XV

HOUSEFLIES

House-Invading Flies.—Many species of flies belonging to various families of Diptera are commonly found indoors; however, relatively few of these species are of public health importance. Flies which habitually enter the house, coming in contact with food or drink and breeding in excrementous material or feeding upon such matter, are a menace. Flies of this character usually belong to but a few families, principally the Muscidae, Anthomyidae, Sarcophagidae (flesh flies), and Calliphoridae (blowflies). Curran (1934 loc. cit.) has combined the Anthomyidae with the

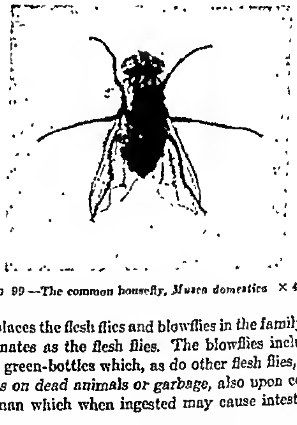

FIG 99.—The common housefly, *Musca domestica* × 4.

Muscidae and places the flesh flies and blowflies in the family Metopiidae, which he designates as the flesh flies. The blowflies include the blue-bottles and the green-bottles which, as do other flesh flies, deposit their eggs or maggots on dead animals or garbage, also upon cold meat and other food of man which when ingested may cause intestinal disturbances.

Family Muscidae.—The family Muscidae, to which the true housefly and several other house-invading species belong, is characterized by Curran (1934 loc. cit.) as including "flies of medium to small size, usually dull colored, the squamae large or of medium size, hypopleural bristles

absent, the second antennal segment grooved above. Arista plumose, pubescent, bare or pectinate, eyes approximate or widely separated in the males, the front rarely narrowed in both sexes; frontal bristles always present, intrafrontals frequently present; orbitals developed but rarely in the males. Abdomen composed of four segments in the male, five in the female. Male genitalia usually not prominent but sometimes conspicuous; fifth sternal lobes sometimes prominent."

The True Housefly.—Hewitt's[1] description (translation from Schiner) of *Musca domestica* Linn. (Fig. 99), the common housefly, is undoubtedly the best for our purpose:

"Frons of male occupying a fourth part of the breadth of the head. Frontal stripe of female narrow in front, so broad behind that it entirely fills up the width of the frons. The dorsal region of the thorax dusty gray in color with [illegible] gray with black sides. The [illegible] the darkest parts at least [illegible] is [illegible] in. [illegible] v[illegible] Median stripe velvety black. Antennae brown. Palpi black. Legs blackish brown. Wings tinged with pale gray with yellowish base. The female has a broad velvety black, often reddishly shimmering, frontal stripe, which is not broader at the anterior end than the bases of the antennae, but becomes so very much broader above that the light dustiness of the sides is entirely obliterated, the abdomen gradually becoming darker. The shimmering areas of the separate segments generally brownish. All the other parts are the same as in the male. Mature insect 6–7 mm in length, 13–15 mm across the wings."

Why called the housefly.—Out of a total of 23,087 flies collected by Howard[2] in dining rooms in different parts of the United States 22,808, or 98 per cent of the whole number, were *Musca domestica* Linn. Again out of a total of 294 flies collected by the writer, representing the entire fly population of one house, 202, or 94.4 per cent, were *Musca domestica* Linn. Thus the term *common housefly* is not misapplied. It is furthermore a cosmopolitan species.

Distribution of sexes.—In order to determine the distribution of the sexes of *Musca domestica* Linn. observations were made under two different conditions, viz., first, six sweepings with an insect net were made over a horse-manure pile on which many flies had gathered (the results are shown in Table VI; second, all but half a dozen flies were collected in one house, giving a fairly representative lot for indoors, even under screened conditions (Table VII).

TABLE VI

SHOWING RESULTS WITH REGARD TO SEX AND SPECIES IN SIX SWEEPINGS FROM A HORSE-MANURE PILE ON MAY 19, 1909

	First		Second		Third		Fourth		Fifth		Sixth		Total	
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
Housefly (*Musca domestica*)	7	153	4	81	3	64	9	77	4	210	5	112	32	697
Muscina sp.	2	6	0	7	0	5	2	5	3	10	1	4	8	37
Blowfly (*Calliphora* sp.)	2	2	0	1	1	0	0	0	0	0	1	0	4	3
Lucilia sp.	0	1	0	1	0	1	0	1	0	0	0	0	0	4
Other species	1	4	0	4	2	1	4	2	4	2	2	0	13	13
Totals	12	166	4	94	6	71	15	85	11	222	9	116	57	754

TABLE VII

SHOWING NUMBER OF INDIVIDUALS COLLECTED IN A SCREENED DWELLING JUNE 1, 1909, REPRESENTING THE ENTIRE FLY POPULATION OF THE SAME

	♂	♀
Housefly (*Musca domestica*)	86	116
Muscina sp.	3	1
Homalomyia sp.	5	0
Calliphora sp.	1	2
Totals	95	119

These two tables give us some information as to the relative abund ance of the housefly, and the distribution of the sexes. Table VII show clearly that of those flies which frequent both the manure pile and th home, the true housefly (*Musca domestica* Linn.) composes 90 per cent and that of the total collected, over 95 per cent (95.4 per cent) wer females. Thus, it is clear that it is the "instinct" to oviposit (to lay eggs that has mainly attracted these insects to the manure. In fact, freshe parts of the manure pile are often literally white with housefly eggs in countless numbers. Observations made in the near vicinity of the manure piles proved that certainly the same percentage (over 95 per cent) of the flies clinging to the walls of the stable, boxes and so on were males.

That the number of males and females in the housefly is normally about equal is evidenced by the fact that of a total of 264 pupae collected indiscriminately and allowed to emerge in the laboratory, 129 were males and 135 were females.

Of the total number of houseflies (202) collected indoors (June, 1909), representing all but perhaps six of the total number in that particular house, 57 per cent were females, showing nearly equal distribution for the

sexes. This would, it seems, indicate that males and females are equally attracted to the house by odors issuing therefrom.

Life history of the housefly.—The housefly passes through a complex metamorphosis (Fig. 16) i.e., egg, larva (maggot), pupa and adult or fully winged insect. Under warm summer temperatures the egg stage requires about 20 hours, the larval stage about five days, the pupa about four days, a total of about 10 days from egg to adult insect. This allows for the development of from ten to twelve generations in one summer.

From 75 to 150 eggs are deposited singly, piling up in masses, and there are usually several such layings at intervals of three or four days. Female flies begin depositing eggs from 9 to 12 days after emerging from the pupa case. Dunn,[8] Entomologist, Board of Health Laboratory, Ancon, Canal Zone, reporting on his observations, states that as many as 159 eggs may be deposited in one batch, that large batches are sometimes deposited at intervals of but 36 hours, and that one female may deposit as many as 21 batches, or a total of 2,387 eggs, in 31 days after emergence. He also states that oviposition may take place as early as 2½ days after emergence, and that copulation may occur within 24 hours after emergence and one successful copulation seems to be sufficient to fertilize the female for her lifetime. Under our laboratory conditions houseflies reach sexual maturity in three or four days and begin depositing eggs on the ninth day after emergence from the puparium. Sunshine stimulates their breeding habits Egg laying may continue throughout the lifetime of a fly, i e., for more than two months.

Influence of temperature on life history.—While conducting an extensive series of experiments in which many hundreds of houseflies were used in all stages, a record was made of the temperature at which the containers were kept. Ordinarily not more than one to three quarts of manure were used for the growing maggots, hence the temperature of the environment did not differ widely from that of the manure. The temperature of an average manure pile to which material is added daily varies from 18° C. to 66° C. Young growing larvae are most numerous at temperatures varying from 45° to 55°. Below 45° half-grown and full-grown larvae occur and above 55° the temperature seems to become too great.

From the following table (Table VIII) it will be seen that temperature influences the time required for the development from egg to imago very materially, but nevertheless with an average outdoor temperature of 18° C. flies ordinarily require only from 12 to 14 days to pass through the same stages; this is, of course, due to the higher temperature of the manure pile, as already indicated above. The shortest time required for

complete metamorphosis of *Musca domestica* Linn. is seen to be 9⅓ days, and that at 30° C.

TABLE VIII

SHOWING INFLUENCE OF TEMPERATURE ON THE LENGTH OF LIFE HISTORY OF MUSCA DOMESTICA

The insects were kept at the temperature indicated from egg to emergence of the imago. The average temperature is here given, the variation from the average was probably not more than ± 1°. Temperature of the air and not of the manure is here considered.

	16° C		18° C		20° C		25° C		30° C	
	Min	Max.	Min.	Max.	Min.	Max.	Min.	Max	Min	Max
Egg stage	36 hrs.	40 hrs.	27 hrs.	30 hrs.	20 hrs.	30 hrs	12 hrs	20 hrs.	8 hrs.	12 hrs.
Larval stage	11 ds.	26 ds	10 ds.	14 ds.	8 ds.	10 ds.	7 ds.	8 ds.	5 ds	6 ds.
Pupal stage	18 ds	21 ds	12 ds	15 ds	10 ds.	11 ds	7 ds	9 ds	4 ds.	5 ds.
Total time required from egg to imago	40½ ds.	48¾ ds	23¼ ds	30¼ ds	18¾ ds.	22½ ds.	14½ ds.	17¾ ds	9¼ ds	11½ ds
Average time required to develop from egg to imago	44.8 days		26.7 days		20.5 days		16.1 days		10.4 days	

Excrement preferred.—Excrementous material, especially of horses (Fig. 100), is the favorite material upon which the eggs of *Musca domestica* Linn. are deposited and on which the larvae feed. Other suitable materials are garbage, kitchen refuse, brewer's grain and other decomposing vegetable and animal matter. Under rural conditions it seems quite safe to say that 95 per cent of the houseflies are bred in horse manure. The housefly does not breed so abundantly in cow manure, although plentifully enough to take such material into consideration, especially when it occurs in piles mixed with bedding. The eggs of the housefly hatch in from 12 to 24 hours; the newly hatched larvae begin feeding at once and grow rapidly.

To gain an estimate of the number of larvae developing in an average horse-manure pile, samples were taken after four days' exposure to flies, with the following results: first sample (4 lbs.) contained 6,873 larvae; second sample (4 lbs.), 1,142; third sample (4 lbs.), 1,585; fourth sample (3 lbs.), 682; total 10,282 larvae in 15 pounds. All of the larvae were quite or nearly full grown. This gives an average of 685 larvae per pound. The weight of the entire pile was estimated at not less than 1,000 pounds, of which certainly two-thirds was infested. A little arithmetic gives us the astonishing estimate of 455,525 larvae (685 x 665), or in round numbers 450,000.[4]

The larval stage is the growing period of the fly, and the size of the

adult will depend entirely upon the size that the larva attains. An underfed larva will result in an undersized adult. The growing stage requires from four to six days, after which the maggots often crawl away from their breeding place, many of them burrowing into the loose ground just beneath the manure pile, or under boards or stones, or into dry manure collected under platforms and the like. One and three-fourths pounds of dry manure, taken from beneath a platform, contained 2,561 pupae. The larvae spend three or four days in the prepupal or migratory stage before actually pupating; in a given set of individuals under similar conditions the various stages are remarkably similar in duration—when one pu-

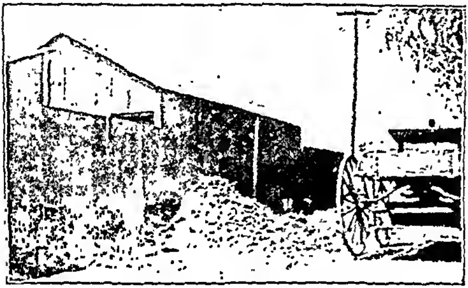

FIG. 100.—A typical rural fly breeding place—the everlasting manure pile. The principal menace is the fresh, warm manure added on top daily.

pates, the rest will certainly follow in short order, and when one emerges, the others quickly follow.

When the fly emerges from the pupa case the wings are folded in tight pads and change in size is due only to expansion and addition in weight and not in growth. Stomach contents or development of eggs in the female add to weight. This is why no young houseflies are seen, i.e., young in the sense of being small. Little flies are not "baby" flies; they are either a different and smaller species or undersized. One can influence the size of the adult fly by underfeeding it in the larval stage (see Herms,[8] 1907).

Estimating that one adult fly deposits from 120 to 150 eggs per lot with at least six lots at intervals of from three to four days, Hodge [8] gives us the following astounding statement: "A pair of flies beginning operations

in April may be progenitors, if all were to live, of 191,010,000,000,000,000,000 flies by August. Allowing one-eighth of a cubic inch to a fly, this number would cover the earth 47 feet deep."

Other breeding places.—While horse manure is certainly a favorite larval food and is commonly regarded as the chief factor in the breeding of houseflies, and certainly is under most rural and village conditions, other factors may arise which are vastly more important, particularly in this day of the automobile and tractor. Cow manure if well mixed with bedding is frequently an important factor in the development of flies Flies will also breed freely in hog manure, but the swarms of flies about the pig pens usually originate in the waste feed, slops, etc. Chicken manure is the most important factor in the breeding of flies in poultry districts and the pest of blowflies in such districts is the result of dead birds buried in shallow pits or simply disposed of by throwing them into a gully or in a corner. The dead birds (large or small) should be burned or buried with crude oil, plenty of lime or sprayed with creosote oil. Human excrement is a very dangerous substance and if exposed to flies in open privies becomes a very prolific breeding place, which emphasizes the need of flyproof privies or other means to prevent flies from gaining access or to repel them.

Great swarms of flies are often found around feed troughs and the animals (hogs and cattle) may be literally covered with them. An examination of the waste feed behind or beneath the troughs or in and about the mixing vats will almost invariably reveal numerous maggots. Storage receptacles for slops sometimes present a wriggling mass of maggots. The correction of such fly-breeding manifestly depends upon greater cleanliness and care in handling the mash, wet or dry. The addition of a very small quantity of turpentine to vessels containing kitchen slops acts as a repellent and is harmless. Spraying feces, walls and floors with creosote oil gives beneficial results also and is not so disagreeable as crude oil or fuel oil, all of which, of course, add somewhat to the fire risk.

It frequently happens that brewer's grain or spent hops, bran mash and ensilage are only partly consumed by the animals and the waste is thrown out into the fields in heaps. Such heaps of waste are commonly a source of enormous numbers of flies about dairies where otherwise conditions may be very good and no apparent reason for the swarms of flies exists. In dealing with such wastes the general principle of scattering the waste in a thin layer so as to hasten drying and thus prevent fly-breeding must be observed.

Garbage heaps, particularly when fermentation and decomposition begin, are commonly sources of many flies of several kinds. Heaps of decaying onions and other vegetables, fruits, *etc.*, as well as decaying

straw and weeds, may become infested with maggots. Spraying such heaps with crude oil or fuel oil gives good results and unless there is danger or some other good reason, a match should be applied. Smoking and smoldering garbage heaps seldom breed flies except where garbage is carelessly added. Every household in every community should be provided with a garbage can equipped with a tight-fitting lid, and all liquid matter should be drained from the kitchen refuse at the sink and only solids placed in the garbage can, and these should first be wrapped in a newspaper. This may seem "finicky," but it is time well spent and it is worth trying, both from the standpoint of fly control and from the standpoint of your nostrils as well. Do not bury garbage except as already explained, and never allow garbage to accumulate in heaps in back yard or alley (Fig. 101).

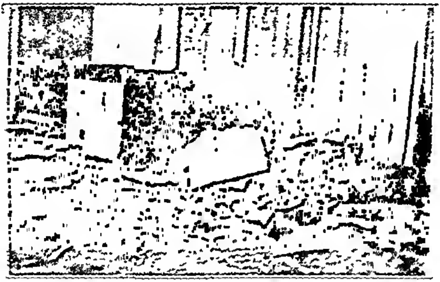

Fig. 101.—A poor excuse for a fly-tight garbage can. This should be regulated by ordinance

In the absence of sewers or septic tanks in the country the dishwater from the kitchen is frequently piped from the sink to a ditch in the back yard. On many occasions these ditches become clogged and vile smelling and an examination will reveal numerous maggots developing in the muck—a source of flies commonly overlooked.

The writer has also seen so-called uncovered septic tanks literally reeking with maggots and he has seen defective covered septic tanks, with open cracks and knot holes, which have been responsible for hordes of flies. Maggots were found in countless numbers in the soft sludge mat covering the liquid in the defective tank. Crevices and knotholes are easily covered, thus preventing breeding within the tanks.

Range of flight.—Ordinarily under city conditions it may be safely said that where flies are abundant they have been bred in the same city block or one immediately adjacent. The housefly can, however, use its wings effeotively and may he carried by the wind, though it usually seeks protection very quickly when there is a strong breeze. Where houses are situated close together flies have the opportunity to travel considerable distances hy easy flights and they are often carried on meat and milk delivery wagons, animals, etc.

In a most illuminating experiment Copeman[7] et al. have shown that houseflies may invade a community at a distance of from 300 yards to 17,000 yards from their breeding place; in this case a refuse heap.

In a certain city in Montana 387,877 marked flies were liberated from a release point and a total of 1,056 flies were recaptured at seventy-eight stations which varied from 50 to 3,500 yards from the point of release.[8]

Longevity of flies.—In order to determine the longevity of flies it is necessary to keep the same individual under observation from the time of emergence from the pupa to the time of death. The writer has done this by keeping each pupa in a separate vial, noting the time of emergence to the hour and spotting each fly lightly with Chinese white dorsally on the thorax. The spots can be arranged singly and in combination so that many different flies can be kept under observation at the same time After marking, the flies were liberated in bobbinet-covered cages (size of cages never more than 8″ x 10″ x 18″). Each cage was provided with sugar water and a receptacle of horse manure. A full set of experiments under sufficiently varying conditions indicate an average life of close to 30 days with a maximum life of something over 60 days during the summer months. In hibernation flies may live over winter, i.e., from October to April, which is the case in our eastern and central states. In California, flies emerge from their pupa cases throughout the winter, and their life history is then considerahly longer than in summer.

Other house-invading flies.—*Fannia* (=*Homalomyia*) *canicularis* (Linn.), commonly known as the *lesser housefly*, is frequently seen hovering in mid-air or flying hither and thither in the middle of the room. Where the common housefly is encountered most abundantly in the kitchen or dining room, particularly on food, the "little housefly" will be seen as commonly in one room as another, and very seldom actually on the "spread" tahle. The writer commonly observes a half dozen or more of these little flies dancing weirdly in the center of the lecture room midway hetween the floor and the ceiling. Various observers have estimated that this species constitutes from one to 25 per cent of the total population of flies in the average house.

In size the species varies from 5 to 6 mm. Its color is grayish, resembling the housefly very closely. Hewitt describes it as follows:

"Head iridescent black, silvery white, especially around the eyes. The antennae are blackish gray with non-setose arista. Palps black. The thorax is blackish gray with three indistinct black longitudinal stripes; the scutellum is gray and bears long setae; the sides of the thorax are lighter. . . . The legs are black, and the middle femora bear comb-like setae below. The somewhat large squamae at the bases of the wings are white and the halteres are yellow. . . . The head of the female is gray with a wide frons, black frontal stripe and gray sides. The longitudinal stripes of the thorax are faint and the abdomen, which is more pyriform than that of the male, has a slightly golden attachment."

The eggs of this species are deposited on decaying vegetable matter and excrement, particularly of humans, horses and cows. The larvae emerge in about 24 hours and may be recognized as compressed, spiny organisms about 6 mm. long when full grown (Fig. 102). The pupal period lasts about seven days under favorable conditions.

Fannia (=*Homalomyia*) *scalaris* (Fabr.), the latrine fly, is very similar to the foregoing. In size the two flies are about the same, if anything the latrine fly is somewhat the larger. The thorax and abdomen are bluish black, the antennae and palpi are black as are the legs. The abdomen has a dark median stripe which, with segmentally arranged transverse bands, produces a series of dorsal triangular markings. The middle tibia is provided with a distinct tubercle.

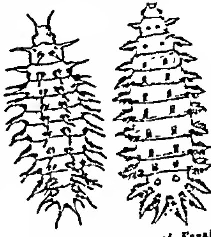

FIG 102.—(a) Larva of *Fannia* (=*Homalomyia*) *canicularis*; (b) Larva of *Fannia* (=*Homalomyia*) *scalaris* (Redrawn and adapted after Hewitt) × 6

The eggs of this fly are deposited on excrement of humans, horses, cows, etc., also on decaying vegetable matter. The egg stage lasts about 24 hours, the larval stage about six days and over, and the pupal stage about nine days.

While the larva of the "latrine fly" resembles the larva of the lesser housefly in general, it is readily distinguished by the single lateral protub[illegible] feathered (Fig 102). [illegible] Fabr.) is described by Austen* wh[illegible] [illegible]efly" should be read by all sanitary officers interested in housefly [illegible]ems:

"though agreeing approximately with the housefly in length, is a bulkier, more compactly built and thick-set insect . . . is often decidedly larger. In the male the upper surface of the abdomen has a black base, from which there is a backward prolongation in the shape of a longitudinal, median stripe, both base and stripe being sharply defined, and presenting a well marked contrast to the cinna-

mon-buff of the remaining ground-color; in the female the upper surface of both thorax and abdomen is grey, with darker markings. In the case of both sexes, however, the surest criteria for distinguishing *Musca autumnalis* from *M. domestica* are those presented by the upper surface of the head. Whereas in the male of *Musca autumnalis* the eyes are so close together as to be almost or actually in contact at one spot, in the male housefly the space between the eyes is always much broader, and, as already indicated, may be nearly equal to one-fourth of the total width of the head. As regards the opposite sex, in the female of *Musca autumnalis* the black longitudinal area (frontal stripe) in the center of the space between the eyes is approximately equal in width to the grey border on each side, separating it from the corresponding eye. In the female housefly, however, the frontal stripe is much broader, and its width greatly exceeds that of the border, yellowish-golden in front and below, blackish above, on each side of it. The resting position of the wings in *Musca autumnalis* is the same as in *M. domestica*. In the autumn, in country districts in the British Islands, *Musca autumnalis* frequently enters houses and public buildings, sometimes in large numbers, and subsequently hibernates in attics, roof-lofts, towers, in the folds of curtains in disused rooms, and in similar retreats."

Major Austen reports that it breeds in cattle droppings scattered in the field.

Muscina stabulans (Fallen) is larger and more robust than the true housefly, varying in length from 7 to nearly 10 mm. Its general appearance is dark gray. The head is whitish gray, the antennal arista bears setae on both the upper and lower sides. The thorax is gray with four longitudinal black lines: the abdomen is almost black in color, covered with gray in places, giving it a blotched appearance. The legs are slender and are reddish gold or cinnamon in color. The wings are folded like *Musca domestica* Linn.; the "fourth longitudinal vein is not elbowed and converges but slightly towards that of the vein before it" (Austen). The eggs of this species are laid upon decaying organic matter and excrement, inclusive of human and rotting cow dung, in which the larvae develop. The complete life cycle is said to require from five to six weeks.

Pollenia rudis (Fabr.), the cluster fly, may be distinguished from all other houseflies in that the wings when not in use close over each other at the tips scissors-like. According to Austen it measures normally about one-third inch in length; it is thus as a rule a much larger insect than the true housefly. It is more heavily built and slower in its movements. Austen continues the description:

"The upper surface of the dark greyish-olive middle region of the body (thorax) is clothed with a thick coat of fine, silky, recumbent, yellowish or golden-yellow hair, easily visible to the naked eye, and, though readily rubbed off, still recognisable with the aid of a lens even in a much damaged specimen. The iron grey upper surface of the posterior division of the body (abdomen) is mottled with shimmering metallic patches of lighter grey. (In 1908) Dr. D Keilin, working in Paris, made the extraordinary discovery that the maggot of the cluster-fly is an internal parasite of a small earthworm (*Allolobophora*

chlorotica, Sav.)", which like the fly itself, is exceedingly common and widely distributed in Europe, North America, and elsewhere. "The popular name of the insect (namely cluster fly) is due to the habit of this fly of clustering together, sometimes in very large numbers like a swarm of bees, when hibernating in houses or other buildings."

Blowflies and flesh flies.—The blowflies inclusive of the bluebottles and green-bottles (usually included in the family Calliphoridae[10]) as well as the flesh flies (family Sarcophagidae of most authors[11]), are conveniently placed in the family Metopiidae. Curran characterizes this family as follows:

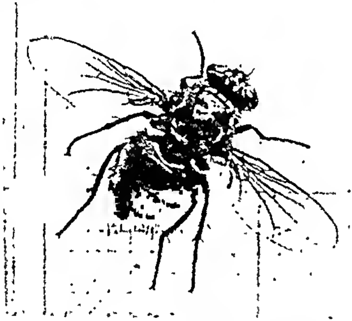

FIG 103.—A common blowfly, *Calliphora vomitoria*

> "Flies of medium to moderately small size, the abdomen usually dark and tessellate or metallic green or blue Front in both sexes broad, usually somewhat narrowed in the males, rarely very narrow, vibrissae present, antennae long or short, the arista plumose, pubescent or bare Abdomen composed of four segments in the males, the fifth short in the females, abdominal bristles usually strong, at least on the apical segments Hypopleura with a row of bristles; postscutellum developed only in *Mesembrinella* Apical cell usually open, rarely closed and petiolate, usually ending far before the apex of the wing . . . The absence of the postscutellum distinguishes the family from the Tachinidae while the presence of hypopleural bristles separates it from the Muscidae"

The larvae of the blowflies and flesh flies usually feed on dead animals, garbage, excrement, etc They are primarily scavenger in habit.

Calliphora.—There are but two common species of bluebottle or

calliphorid flies, although there are many described species. *Calliphora vomitoria* (Linn.) has black genae with golden red hairs, while *C. erythrocephala* (Meig.) has fulvous genae with black hairs (Fig 103). The eggs of these species hatch in from 6 to 48 hours, the growing larvae feed on the flesh for from three to nine days, after which the fully grown larvae leave the food and bury themselves in loose earth. This period (prepupal period) lasts from two to seven days, commonly four, after which pupation takes place. The pupal period varies considerably according to temperature, lasting from 10 to 17 days, commonly 11 days. Thus the life history of the blowfly requires from 16 to 35 days, commonly 22 days. The life of the adult is about 35 days on an average.[12]

Lucilia caesar (Linn.), a common species of green-bottle fly, is commonly found indoors although it is typically a scavenger fly. The abdomen is brilliantly metallic green or copper. There are two post-acrostical bristles. The life history of this species is somewhat shorter than that of the bluebottle. The egg stage requires from 6 to 48 hours; the growing (feeding) larval stage requires from three to seven days, commonly five days; the prepupal period, commonly six days; and the pupal period from 8 to 34 days, commonly 12 days, giving a total of from 16 to 60 days and over, commonly 24 days. Under optimum conditions this fly invariably requires 15 days for its metamorphosis; the average longevity of the fly is about 30 days.

Lucilia sericata (Meig.), like all species of *Lucilia*, is of brilliant metallic color varying, however, in this species from metallic blue and green to copper. It too may occur indoors and is also typically a scavenger. The palpi are yellow. There are three post-acrostical bristles present. The second abdominal segment is devoid of marginal macrochaetae [present in *L. sylvarum* (Meig) which also has black palpi]. At a temperature of 80° ± 2° F. with beef lung or fish as food, the entire life history of *Lucilia sericata* (Meig.) from the deposition of the egg to emergence of the fly requires about 12 days—egg stage, egg hatching same day if deposited during early morning, about eight hours; larval stage (feeding period) about two and a half days; prepupal stage (migrating larvae) about three days; pupal period about six days. *L. sericata* (Meig.) lends itself well to rearing in large numbers for experimental purposes. Rearing procedures are described by Dorman, Hale and Hoskins.[13]

The size of the flies and the sex ratio [14] varies according to the amount of food available during the larval or feeding stage. The sex ratio of 2.8 to 3.1 males to 6.9 to 7.2 females for flies resulting from larvae which fed until they left the food voluntarily, i.e., from 72 to 78 hours, is reversed to 6 2 to 6.5 males to 3 5 to 3.8 females in flies in which the larvae were permitted to feed only 30 to 36 hours, i.e., underfed.

Sarcophaga haemorrhoidalis (Fall.) occurs throughout North America as well as Europe, Asia and Africa. It measures 10 to 14 mm. in length, in color it is gray. The terminalia of the female are red. It reminds one of an overgrown housefly, but is lighter gray and the eyes are brighter reddish brown in color and it is larviparous. The larvae have a wide range of feeding habits, being, however, primarily scavengers. They feed on dead insects, carrion, mammalian excrement, etc.

The larvae are readily deposited on one's hand while holding the female fly. The life history in the presence of ample food and warm temperature requires from 14 to 18 days. The growth of the larvae is very rapid after extrusion when food such as carrion is available. The larval stage may be completed in about three days, followed by the prepupal

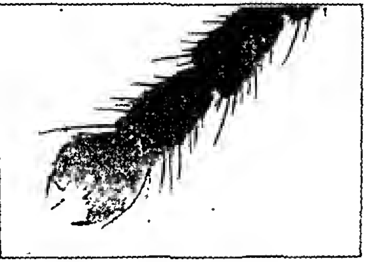

Fig 104 —Foot of the common housefly (Much enlarged)

or migratory stage lasting usually about three days. The pupal stage requires from 8 to 10 days.

Germ carriers.—The common housefly, *Musca domestica* Linn., is by accident of habit and structure an important and dangerous disease-transmitting insect. In habit the housefly is revoltingly filthy, feeding indiscriminately on excrement, on vomit and sputum, and is, on the other hand, equally attracted to the daintiest food of man The housefly's proboscis is provided with a profusion of fine hairs which serve as collectors of germs and filth, the foot (Fig 104) of the fly when examined under the microscope presents an astonishing complexity of structure. Each of the six feet is equally fitted with bristly structures and pads which secrete a sticky material, adding thus to their collecting ability When the fly feeds it regurgitates droplets used in liquefying solid food, and extrudes droplets of excrement as well The structural characters, added to the

natural vile habits of the housefly, make it an ideal transmitter of infectious diseases of certain types.

The common housefly has long been known to contaminate food, but has, nevertheless, been regarded as a scavenger, and thus a beneficial insect; however, if there remains any doubt in the mind of the reader as to its harmfulness, after pondering what follows, let him take the time to make a few careful observations for himself.

In order to show that the housefly (*Musca domestica* Linn.) can carry "germs" of a known kind, a partially sterilized fly was placed in a test tube containing a culture of *Staphylococcus aureus*. After walking about in this tube and becoming contaminated with the *Staphylococci*, the fly

FIG 105.—Cultures of *Staphylococcus aureus* transferred by a housefly to a sterile agar plate upon which it was allowed to crawl for three minutes. Incubation period 24 hours.

was transferred to a sterile agar plate upon which it was allowed to walk for three minutes. The plate was then incubated for twenty-four hours, after which it was examined and photographed. Figure 105 shows the trail of the fly; every place that the foot touched is plainly marked by a vigorous bacterial growth. That the fly cannot easily get rid of all the bacteria on its feet is also illustrated by this photograph, inasmuch as three minutes spent crawling about on the agar plate did not apparently lessen the growth-vigor of bacteria deposited, and a second agar plate contaminated by the same fly immediately after exposure of the first plate gave equally astonishing results. The same experiment was per-

formed, using *Serratia marcescens* Bizio (*Bacillus prodigeosus* Flügge) with even more pronounced results. These experiments were repeated several times with like effect.

Esten and Mason [15] in the "Sources of Bacteria in Milk" state:

> "The domestic fly is passing from a disgusting nuisance and troublesome [illegible] small, while later the numbers are comparatively very large. The place where flies live also determines largely the number that they carry. *The average for 414 flies was about one and one-fourth million bacteria on each.* It hardly seems possible for so small a bit of life to carry so large a number of organisms. The objectionable class coliaerogenes type was two and one-half times as abundant as the favorable acid type."

A very excellent and significant study has recently been made by Yao, Yuan and Huie (Nat'l Med Journ. China, vol. 15, no 4, pp. 410–418, 1929) for Peiping, China. Their studies are based on a total of 384,193 flies, of which 98.4 per cent were *Musca domestica* Linn., 1.1 per cent *Fannia canicularis* (Linn.) and *F. scalaris* (Fabr.), 0.31 per cent *Lucilia caesar* (Linn.), 0.16 per cent *Calliphora erythrocephala* (Meigen) and *C. vomitoria* (Linn.), and 0.03 per cent *Sarcophaga carnaria* (Linn.). They found an average of 3,683,000 bacteria per fly in the slum district, and 1,941,000 for the cleanest district. They found eight to ten times as many bacteria in the inside of the flies as on the outside.

From the experiments previously cited it may be seen that the fly becomes infected by walking over infective materials, both its feet and wings becoming contaminated. The intestinal contents of flies become charged with infection when feeding on infective material, and bacteria are dejected in the fly "specks," and vomit droplets. It furthermore seems plausible that flies might become infected in the larval stage by developing in infectious fecal matter and that the newly emerged and unfed flies would be dangerous. Under experimental conditions Graham-Smith [16] has produced infected blowflies by feeding the larvae on meat infected with spores of *Bacillus anthracis*. He found that the blowflies remained heavily infected for at least two days after emerging and that the bacilli could be cultivated either from the legs and wings or intestinal contents of flies more than fifteen or nineteen days old.

Human foods are contaminated by flies primarily by direct contact through the touch of feet, proboscides and wings; and, secondly, through fly "specks" (feces) and vomit droplets; and, finally, flies grossly infect liquids by accidentally dropping into the fluid—this is especially true of milk.

The opportunity for flies to become infected is so great in all com-

munities, even the most sanitary, that no fly should be trusted to alight on food prepared for human consumption. The following quotation from Nuttall[17] is directly to the point:

> "It should be ...
>
> agents than, for instance, a sample of infected water. In potential possibilities the droppings of one fly may, in certain circumstances, weigh in the balance as against buckets of water or of milk."

Leidy[18] in 1871 expressed an opinion that flies were probably a means of ...

... in which hospital gangrene had existed during the Civil War, he thought flies should be carefully excluded from wounds. It was, however, not until the Spanish-American War in 1898 that the real menace of the fly became evident as indicated by the following quotation from an article by Veeder in the Medical Record of September 17, 1898:

> "To clinch the argument, and apparently to leave no loophole for escape, I have made cultures of bacteria from fly tracks and from the excrement of flies, and there seems to be not the slightest difficulty in so doing. Indeed the evidence of every sort is so clear that I have about reached the conclusion that the conveyance of infection in the manner indicated is the chief factor in decimating the army."

The following quotation from routine orders (846, April 16, 1917) concerning sanitation in the operations of the Fourth Army (British) is indicative of the importance in which fly control was held during the World War:

> "1. The approach of warmer weather makes it imperative that all ranks should appreciate the necessity for taking every possible precaution to safeguard the health of the troops during the coming summer.
>
> "It must be impressed upon all ranks that their comfort and immunity from preventable disease will dep... surroundings and ...
>
> this necessary work and the responsibility for seeing that it is done must be extended down to the commanders of platoons and other small units.
>
> "2. During the offensive of last year certain epidemic diseases gained a considerable hold, and there is good reason to believe that most formations which took part in the Battle of the Somme include men who are carriers of disease germs. The universal and conscientious observance of the rules of sanitation is, therefore, necessary, if an epidemic of a serious nature is to be warded off.
>
> "3. The diseases in question, the most prevalent of which is Dysentery, all

belong to the so-called Enteric group. The germs which cause these diseases are spread through the feces and urine of patients—early cases, slight cases, convalescents and carriers The diseases are literally caught by the swallowing of infected matter introduced into the mouth in water, or in food contaminated by flies, dust, mud or dirty hands. The sanitary measures detailed below all aim at the prevention of this swallowing of filth

"4. It is a breakdown of ordinary sanitation which is most to be feared and guarded against. When excreta lie exposed and are trodden about, when flies swarm from latrines to cookhouses and to uncovered food, or when shell hole water is the only water available, then infection is inevitable."

Gastro-intestinal diseases.—The housefly is primarily a food contaminator and vector of filth diseases because of its feeding and breeding habits as already explained. Pathogenic organisms are collected on feet and mouth parts and ingested while feeding, then deposited mechanically while the fly is crawling on human food or deposited by regurgitation or with the fly's excrement.

Of the housefly's ability to transmit typhoid bacilli, Jordan [19] writes:

"Not only may bacilli stick to the legs and wings of these insects, but if swallowed they may survive the passage of the alimentary tract. Typhoid bacilli have been isolated from houseflies captured in houses in Chicago, in the neighborhood of badly kept privy vaults used by typhoid patients, and it has been shown experimentally that living bacilli may remain in or upon the body of flies for as long as twenty-three days after infection."

The writer's attention was at one time called to a series of sporadic cases of typhoid fever, plausibly traceable to flies, thus: a certain carpenter, recently recovered from typhoid fever, resumed his work on a building on the outskirts of town, making use of a temporary box privy, as was common practice. In the immediate vicinity there lived a milk dealer, who, after washing his cans, placed them on the roof of a shed to drain. Flies are fond of milk, even highly diluted with water. The patients with the cases of typhoid fever in question were, on investigation, found to be customers of this particular dealer. The argument is good and reasonably conclusive.

Yao, Yuan and Huie (loc. cit.) found *Shigella* (=*Bacillus*) *dysenteriae* (Shiga) in 15 out of 50 batches of one hundred flies tested. Alimentary tracts of flies also revealed cysts of *Endameba histolytica*. They found neither *Eberthella* (=*Bacillus*) *typhosa* (Zopf) nor *Vibrio comma* (Schroeter). The specific death rate for gastro-intestinal diseases roughly paralleled the number of flies captured.

Faichnie (Journ. Med. Assoc. So. Afr., vol. 3, no. 23, pp. 669-675, 1929) in a recent study of the etiology of enteric fever comes to the conclusion that comparatively little typhoid is carried on the feet of flies, but he found that both *E. typhosa* and *Salmonella paratyphi* (Kayser)

(*B. paratyphosus* A) multiplied in the intestines of flies fed on infe excrement.

Cholera was among the first diseases with which the housefly associated as a carrier, and the experimental evidence is truly convinc Tizzoni and Cattani in Bologna in 1886 isolated cholera vibrios from caught in cholera wards. Simmonds in 1892 captured flies in the p mortem morgue in Hamburg and isolated cholera vibrios from thes large numbers. "Upon the surface of vegetables and fruits kept in a moist place, experiments have shown that the spirillum may retain vitality for from four to seven days" (Jordan).

In their study of the epidemiology of cholera, Gill and Lal (Ind Journ. Med. Res., vol. 18, no. 4, pp. 1255–1297, 1931) have found evide to support the startling suggestion that possibly one phase of the cycle of the cholera vibrio is passed in the body of the housefly. T results of their work show that the vibrios disappear from the body of fly after about 24 hours but reappear on or about the fifth day, at whi time the fly is capable of infecting food by its feces. Apparently t insect is not only a mechanical vector but may be involved in biologi transmission.

Yaws (Framboesia or tropical ulcer) is caused by *Treponema pe tenue* Castellani. The disease is widely distributed in the tropics. T spirochaetes are found in the superficial ulcers on the hands, face, fe and other parts of the body. The following quotation from Nuttall an Jepson (1909, loc. cit.) is convincing enough that *Musca domestica* Lin is amply able to transmit this disease:

"Castellani (1907) tested the matter of the fly transmission of yaw by experimental methods. He allowed *M. domestica* to feed (1) upo yaws material (scraping from slightly ulcerated papules), and (2) upo semi-ulcerated papules on the skin of these yaws patients. In both case he was able to discover the *Spirochaeta pertenuis* in microscopic prepa rations made from the flies' mouth parts and legs. Furthermore, h allowed *M. domestica* to feed on yaws material (1 and 2 as above) an afterwards transferred them to scarified areas upon the eyebrows o monkeys. Of 15 monkeys thus experimented upon, three developed yaw papules at the places which had been contaminated by the flies."

Ophthalmia.—In commenting on ophthalmia as carried by flies Howard (1911, loc. cit.) has the following to say:

"Dr. Lucien Howe of Buffalo informed the writer (Howard) that in his opinion the ophthalmia of the Egyptians is also transferred by flies and presumably by the housefly, and referred the writer (Howard) to a paper which he read before the Seventh International Congress of Ophthalmology at Wiesbaden in 1888. He referred to the extraordinary prevalence of purulent ophthalmia among the natives up and down the river Nile and to the extraordinary

abundance of the flies in that country. He spoke of the dirty habits of the natives and their remarkable indifference to the visits of flies, not only children,

when the flies are present in the greatest numbers and the eye trouble is most prevalent in the place where the flies are most numerous. In the desert, where flies are absent, eyes as a rule are unaffected. He made an examination of the flies captured upon diseased eyes and found on their feet bacteria which were similar to those found in the conjunctival secretions. Flies captured in Egypt swarming about the eyes of ophthalmia patients and sent to Washington, D. C., were identified as *Musca domestica*."

Eggs of parasitic worms.—The most extensive and careful work on the dispersal of eggs of parasitic worms by the housefly has been done by Nicoll,[20] and the following is a summary of his investigations in that respect. Flies feed readily upon infective material such as excrement laden with eggs from parasitic worms and even upon evacuated worms. Eggs may be conveyed by flies from excrement to food in two ways, namely on the external surface of their body and in their intestines. The latter mode is practicable only when the diameter of the eggs is under .05 mm. Eggs with a diameter of up to .09 mm. may be conveyed on the external surface, however, these adhering eggs are usually got rid of by the fly within a short time, while those harbored in the intestine may remain there for two days or longer.

The eggs may remain alive and subsequently cause infection in either of these ways; however, this depends on their resisting powers. It was found that material containing eggs of parasites, and in particular ripe segments of tapeworms, remain a source of infection through flies as long as two weeks.

The eggs of the following parasitic worms were shown experimentally to be capable of transmission by *Musca domestica* Linn.: *Taenia solium* Linn., *Taenia pisiformis* (Bloch), *Taenia hydatigena* Pallas, *Hymenolepis nana* (v. Siebold), *Dipylidium caninum* (Linn.), *Diphyllobothrium latum* (Linn.), *Enterobius vermicularis* (Linn.), *Trichocephalus* (=*Trichuris*) *trichiurus* (Linn.), both internally and externally, *Necator americanus* (Stiles), *Ancylostoma caninum* (Ercolani), *Ascaris equorum* Goeze, *Toxascaris leonina* (v. Linstow), *Hymenolepis diminuta* (Rudolphi), externally only. No trematode parasites were experimented with and the observations of Stiles that the larval fly can ingest ascarid eggs and pass them on to the adult fly was not confirmed.

Plague.—Flies probably have little or nothing to do with the transmission of *Pasteurella pestis* of plague under usual conditions, but it has long been known that the larvae of flesh flies feeding on dead-plague rats carried in their bodies the organism of this disease; indeed it is be-

lieved by some workers without much supporting evidence, however, that flies reared from such infected larvae suffer a high mortality due to plague. Russo (reported in Rev. Appl. Ent. xix, Ser. B, pp. 86–87, April, 1931) found that fly larvae taken from infected rats and pupae and adults reared from them were all positive when tested for the presence of plague bacilli. Plague bacilli were found in the dejecta of the adult flies. The species of flies involved in Russo's investigations were *Musca domestica* Linn. *Calliphora vomitoria* (Linn.), *Sarcophaga carnaria* (Linn.), and *Lucilia caesar* (Linn.).

Tuberculosis.—"The belief that flies (*Musca domestica*) which have fed on tubercular sputum may serve as carriers and disseminators of the tubercle bacillus first led Spillmann and Haushalter (1887) to investigate the problem. They examined such flies and also their excreta deposited on the walls and windows of a hospital ward, and were able to determine microscopically the presence of large numbers of tubercle bacilli, both in the intestines of the flies and their excrement" (Nuttall, 1899).

Howard quotes the following from a "paper by Dr. Frederick T. Lord (1904) of Boston":

"1. Flies may ingest tubercular sputum and excrete tubercle bacilli, the virulence of which may last for at least fifteen days.

"2. The danger of human infection from tubercular flyspecks is by the ingestion of the specks on the food. Spontaneous liberation of tubercle bacilli from flyspecks is unlikely. If mechanically disturbed, infection of the surrounding air may occur.

"As a corollary to these conclusions it is suggested that—

"3. Tubercular material (sputum, pus from discharging sinuses, fecal matter from patients with intestinal tuberculosis, etc.) should be carefully protected from flies, lest they act as disseminators of the tubercle bacilli.

"4. During the fly season greater attention should be paid to the screening of rooms and hospital wards containing patients with tuberculosis, and laboratories where tubercular material is examined.

"5. As those precautions would not eliminate fly infection by patients at large, foodstuffs should be protected from the flies which may already have ingested tubercular material."

The investigations by Dr. Ch. André of the University of Lyons were reported at the Anti-Tuberculosis Congress at Washington, 1908:

"Flies are active agents in the dissemination of Koch's bacillus because they are constantly going back and forth between contagious sputa and feces, and foodstuffs, especially meat, fruit, milk, etc., which they pollute by contact with their feet, and especially with their excretions.

"The experimental researches of the author show the following:

"1. Flies caught in the open air do not contain any acid-fast bacilli that could be mistaken for the bacillus of Koch.

"2. Flies that have been fed on sputum evacuate considerable quantities of

bacilli in their excretions. The bacilli appear six hours after ingestion of the sputum, and some may be found as long as five days later. These flies, therefore, have plenty of time to carry these bacilli to a great distance, and to contaminate food in houses apparently protected from contagion, because not inhabited by consumptives.

"3. Food polluted by flies that have fed on sputa contains infective bacilli and produces tuberculosis in the guinea pigs.

"4. Flies readily absorb bacilli contained in dry dust

"5. Flies caught at random in a hospital ward produced tuberculosis in the guinea pig."

André's conclusions are: "The sputa and feces of tuberculosis subjects must be disinfected; flies should be destroyed as completely as possible; foodstuffs should be protected by means of covers made of wire gauze."

Intestinal Protozoa.—Roubaud [21] found that the cysts of *Endamoeba coli* (Grassi), *Endamoeba histolytica* and *Giardia lamblia* Stiles passed through the intestine of the fly uninjured, and that free amebae (both *coli* and *histolytica*) when fed to flies were found dead in the fly's intestine in less than an hour. Root [22] found motile *Chilomastix mesnili* (Wenyon) in a fly's feces seven minutes after it had fed on a stool containing them.

Murrina.—Murrina, a trypanosomiasis of horses and mules in Panama and the United States, is caused by *Trypanosoma hippicum* Darling and shown by Darling [23] to be transmitted mechanically by houseflies from sick animals to well ones by contact with blood from skin lesions and also in a number of other ways.

Cutaneous habronemiasis.—An examination of certain persistent ulcerations, summer sores, on the lower portions of the bodies of horses which have a tendency to disappear during colder weather, may reveal the presence of larval nematode worms belonging to the genus *Habronema* measuring from 1 to 1.5 mm. in length. The presence of such worms in sores on the eyes is termed *habronemic conjunctivitis*. The adults of these worms such as *Habronema muscae* (Carter), measuring from 8 to 14 mm. in length in the male and 13 to 22 mm. in the female, occur in the stomach of the horse where they lay their eggs which pass out with the feces. The newly hatched larvae find their way into the bodies of fly larvae, which are evidently true intermediary hosts and in which further development occurs. The flies resulting from such larvae may contain a number of such worms (from 1 to 20) in their bodies, often the head. According to Ransom [24] the infection of horses with *H. muscae* is apparently brought about by the swallowing of infected flies or infection by the larvae migrating from the insect as it feeds. The sores above mentioned are evidently the result of larvae entering lesions while the animals are lying down in infected manure

Fowl taeniasis.—Domestic fowls are commonly infested with tape-

worms and the extent to which this may occur is well illustrated in Fig 106. Several species of tapeworms inhabit the intestines of fowls, but although Grassi and Rovelli [25] as early as 1886 had made observations concerning their development, it was not until 1916 that experimental evidence was published by Gutberlet,[26] proving that the housefly (*Musca domestica* Linn.) was used as intermediate host.

FIG 106.—Showing segment of intestine (inside out) of fowl infested with numerous tapeworms, *Choanotaenia infundibulum*.

The most important of the fowl tapeworms is *Choanotaenia infundibulum* (Bloch). It measures from 50 to 200 mm. in length. The scolex is small and rounded, measuring about 0.4 mm. in width The rostellum is armed with a single row of 16 to 20 hooks. The cysts found in the housefly are oval in shape and measure about 200μ in length by 120μ in diameter. Gutberlet infected the adult flies by feeding them on liquids which were infected with tapeworm eggs, and it is assumed that fly larvae breeding in infected fowl droppings would become similarly infected Reid and Ackert [27] in experiments with this tapeworm recovered proglottids in fowl feces at the end of the seventh week. These authors point out that buttermilk is very attractive to both flies and chickens and that chickens devour the flies eagerly.

Raillietina cesticillus (Molin), according to Gutberlet, also has the housefly as its host and *Hymenolepsis carioca* (Magal) has *Stomoxys calcitrans* (Linn.), the stable fly, as its host

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CHAPTER XVI

HOUSEFLY CONTROL

Fly control.—Effective fly control is based on a knowledge of the habits and life history of the offending insect. First find the breeding places and then apply the appropriate remedy. The presence of flies always denotes defective disposal of manures, garbage, sewage, slops, food wastes, ensilage, brewer's grain, spent hops, wet mash, dead animals, etc.

Since the principal rural breeding places of the common housefly are usually found in and about stables, particular attention must be paid to stable and stable-yard sanitation, with special reference to the disposal of manures. The stable should have a concrete floor. Although higher than wood in the initial cost, concrete meets the requirement of a good floor better than any other available material. Concrete floors, according to Bulletin No. 97, North Dakota Agricultural Experiment Station, are considered best for several reasons.

"(1) They are economical because they are durable. Wooden floors last from three to five years with a maximum of ten years, if of the best construction, while the *durability of concrete floors equals that of the building.* (2) They save labor because of their evenness, which permits of thorough and easy cleaning. (3) They are sanitary not only because they can be kept clean, but because they are easily drained and are watertight enough to exclude ground water and prevent the liquid manure from leaching into and polluting the soil.

"The chief objection to concrete floors is that they are cold and slippery. To the first may be replied that in reality concrete is no colder than wood subjected to the same temperature but on account of being a better conductor of heat concrete carries away the bodily heat of the animals faster if they come in direct contact with it. This is not a serious objection, for even wood is too cold for animals to lie on without bedding, which should be supplied liberally on any floor. Straw is a poor conductor of heat and if a sufficient amount of bedding is used, the bodily heat of the animals will be retained as well on concrete as on wood, which is apt to be more or less wet or soggy. A generous use of bedding is desirable not only because it adds to the comfort of the animals, but because of the increased amount of manure which in turn means increased fertility of the farm. The objection of slipperiness may be overcome by making the wearing surface scored or grooved into blocks before it has hardened. These sections made from 4 to 6 inches square furnish a good foothold for the animals and make a very neat appearance.

"The floor should be raised about one foot above the surface of the ground to insure drainage. If earth has been filled in to secure this elevation, it must be

thoroughly ---
of the floor.
tion is com
the fill will h... proper time to settle before the *floor* is put on.

"Concrete stable floors should be about 5 inches thick. The lower 4 inches should be *made of concrete* in the proportion of one part cement, 2½ parts clean, coarse sand and five parts screened gravel or broken stone and finished before the concrete has set, with a one-inch mortar of one part Portland cement to two parts clean and coarse, but sharp, sand. If the sand or cement is not *first-class*, this proportion had best be changed, for horse barns at least, to one part cement to 1½ parts sand.

"Before ...
or ...
Th. depth of this foundation will depend upon the drainage of the soil, but *where a fill of* one foot of earth has been provided, as previously described, the foundation need not be more than four inches thick."

In constructing a concrete floor, provision *must be made to carry* away the urine from the animals and the water used in cleansing the floors and stalls. Suggestions from the above-named bulletin are here again useful, namely, the stall floors should be given a one-inch drop from the manger to the manure gutter, which latter should be

"6 *inches deep* and 14 inches wide. In order to facilitate the drainage of the *liquids a 3-inch* U-shaped channel is sometimes made in the bottom of the gutter next to the manure alley, but this is not necessary where a slope is given the gutter bottom The gutter should be given a uniform fall of 3 inches to 100 feet, and the floor of the manure alley should have a slope towards the gutter of 1 inch to 10 feet A small watertight liquid *manure cistern* may be provided outside the barn into which the gutter drains, but if a manure shed is used, the cistern should be in the shed. The gutter should be connected to the cistern by means of a drain pipe effectively trapped like the soil pipe in a house and so arranged that the trap may be easily cleaned."

In towns with sewer facilities connection *may* be made directly with the sewer, dispensing with the manure cistern.

Concrete stall floors may be covered with wood to prevent animals from coming in direct contact with the concrete. If such super-floors are provided, they should be made of heavy two-inch strips three inches wide and as long as the stall. The strips are fastened together by crosspieces (ordinarily flat iron strips), so that a space of about one-half inch remains between the strips. To facilitate handling, it is recommended that the floor be made in two long pieces, each *half* the width of the stall, and fitting closely where they join. In this way the super-floor can be lifted up while the concrete is being cleaned; the crevices between the wood strips can be readily freed from manure by means of a heavy *stream* of water or the use of an iron rod. If the crevices are not also frequently cleaned, fly larvae will develop there very readily.

Manure and odors of manure will attract the female flies even though the stable is somewhat dark. The writer believes that the small extra cost of screening a stable against flies is a good investment, since it not only lessens the opportunity for flies to breed but also adds to the comfort of the animals.

Manure disposal.—Wherever horse manure is piled up and accessible to flies, the opportunity is given for them to breed. As before stated, it requires only about four days for the larvae to reach full growth, after which they begin to migrate into the drier portions of the heap and crawl out into near-by debris, beneath platforms, etc. It is therefore imperative, if fly breeding is to be prevented, that manure be protected against flies from the beginning or that it be rendered undesirable to flies.

Under ordinary rural conditions the most practical method is to remove the manure to the field daily. A cart may be used for this purpose, backed up against the stable doorway where the manure is thrown in and then carted away at once to a field where it is scattered. This saves much time in handling and is sound agricultural practice. Since moisture and warmth are both necessary for the development of fly larvae, the scattered manure cannot serve this purpose.

The Wisconsin Bulletin No. 221 states:

> "Manure is never so valuable as when perfectly fresh, for it is impossible under the best system of management to prevent all loss of its fertilizing ingredients For this reason, whenever possible, the manure should be hauled directly to the field and spread. The system saves time and labor as it involves handling but once. The manure will be leached by the rain and snow, nevertheless the soluble portion will be carried into the soil, where it is needed When spread in a thin layer, it will not heat, so there will be no loss from hot fermentation, and where manure simply dries out when spread on the ground, there is no loss of valuable constituents."

Hence a manure spreader is a valuable part of farm equipment. It is not safe to permit chickens to feed on maggots owing to the fact that the larva of a common and dangerous poultry tapeworm (Fig. 106) is commonly harbored by these insects Farmers and gardeners who wish to use "rotted" manure for fertilizing purposes should screen the heap until the "rotting" process is well under way, when fly breeding will be reduced to a minimum, or, as has already been suggested, the manure may be placed in trenches and covered with lime and earth whenever fresh manure is added or it may be stored in fly-tight composting pits.

Manure wastage.—Piling manure in a barnyard results in a loss of manurial value due to leaching and fermentation, estimated at from 25 to 60 per cent. The Cornell University Experiment Station has carried on investigations which show the loss of valuable plant food when manure is disposed of in the usual exposed manner for six months. When the

manure was tested, it was found that the horse manure had lost 57 per cent and the cow manure 49 per cent in gross weight, and the loss in value based on plant food (nitrogen, phosphorus, and potassium) amounted to 65 per cent for the horse manure and 23 per cent for the cow manure. When manure wet with urine is thrown from the stable on to the heap it contains about 75 per cent water which holds most of the plant food. Exposed to leaching rains and weather the liquid sinks into the ground beneath or flows away. Thus not only does the barnyard manure pile result in flies but also in serious loss to the farmer.

To insure against the loss of liquids and multiplication of flies in the barn, attention must be paid to stall floors to make them tight and to

Fig. 107.—Manure bin in a position to become a fly-breeding cage, instead of a fly preventive. It is suggested that the lid be permanently closed and an opening made directly from the stable into the bin. The manure pile adjoining the bin illustrates the manner of disposal before the bin was built.

a means of conserving the urine from the animals by means of suitable gutters as already explained.

Manure bins.—Under town and village conditions it is ordinarily impracticable to remove manure from the premises daily, hence it must be stored temporarily in special receptacles or bins. Heretofore, stress has been laid on fly-tight receptacles, but unless exceptional care is exercised in operating such receptacles, they actually become fly-breeding cages. The writer early recognized this difficulty and suggested a remedy as below described.

Figure 107 illustrates a manure bin of the earlier type. The manure pile near by illustrates the manner of disposal before the bin was erected.

In this case the lid of the bin must be kept open while the manure is being transferred to it from the stable, and during this time flies enter the box in numbers, and when the lid is closed they are trapped, deposit their eggs and soon the manure is reeking with maggots, and if the bin is not cleaned out before the expiration of 9 or 10 days, myriads of flies emerge and are liberated when the lid is opened.

The bin is built on a concrete floor to prevent rats from nesting underneath. It is painted with creosote inside and ventilation is provided for at both ends by means of screened openings. The screen should be of copper wire to prevent rapid rusting. The front of the bin is provided

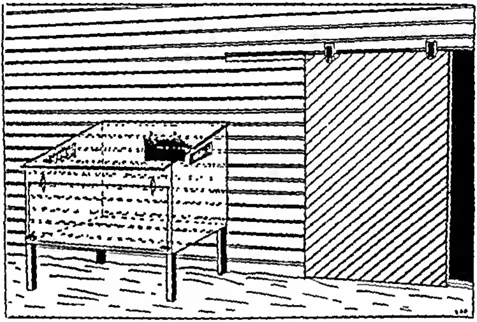

FIG. 103.—A properly constructed manure bin with opening directly from stable into bin. May or may not be elevated on legs to facilitate removal of manure to wagon. Size of bin depends on number of horses and frequency of manure removal

with a hinged door which lifts up, so that the manure can easily be removed. The dimensions are approximately as follows: length, 8 feet; width, 4 feet; height in front, 4 feet; height in back, 5 feet.

The size of the bin, or composting pit if this is used, depends, of course, on the number of horses stabled and the length of time during which the manure remains in storage. It may be estimated that the average horse produces 1½ cubic feet of manure per day, including bedding.

To prevent the bin from becoming a fly-breeding cage, the writer recommends that the top be permanently closed, i.e., without a lid, and that the manure be thrown into the bin directly from the stable through a

small door cut through the side of the stable into the bin near the top of it (Fig. 108). This opening can easily be provided with a small sliding screened door. Furthermore, the bin should be built so that the small door last mentioned can be located in a dark part of the stable, thus further preventing flies from entering the bin. At a small added cost fly-traps can be attached at the ventilator ends of the bin in such a manner that chance flies in the box will enter these. Because the flies respond to the light, they will naturally gather at the ventilator ends, and if the traps are baited with some material attractive to the flies, there is an added inducement to enter.

Composting pits.—Composting pits are frequently used on country estates and truck gardens where quantities of rotted manure are used for

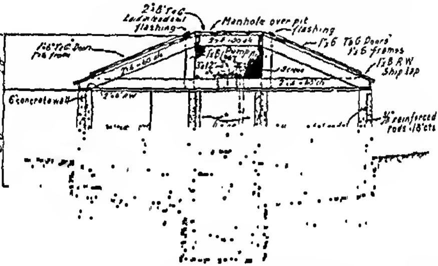

FIG. 109.—Cross section of a concrete fly-proof composting pit. (After Rosenthal in Advisory pamphlet on Camp Sanitation and Housing, Commission of Immigration and Housing of California.)

fertilizing purposes. Such pits are usually made of concrete and covered with wood, all carefully constructed to exclude flies and mosquitoes, which latter may breed in the liquids collected in the sump. A properly constructed composting pit enables one to preserve the urine, which is very valuable in addition to the more solid excreta.

A cross-section of a composting pit is shown in the figure (Fig. 109). In this case a pump is shown by means of which the urine and water are pumped out of the sump and returned to the manure from time to time. Water should be applied to the manure occasionally to prevent burning, which may destroy much of the value of the fertilizer.

The size of the pit depends also on the number of horses stabled. A pit as shown in the figure with a length of sixty feet ought to store the manure from ten horses for a period of six months.

Close packing.—The following description of this method is from Austen (loc. cit.), who states that the essence of this method is the utilization of the natural heat of fermenting manure, for the destruction of the eggs, maggots, and pupae (if present) of the housefly.

"For *close packing* (a method introduced in 1915 by Lieut.-Colonel S. A. Monckton Copeman), an area of hard, level ground, at least three or four feet greater in extent each way than the ultimate size of the intended dump, must be selected or prepared to receive the manure. On this, each day's manure is utilised in forming or adding to a compact rectangular block, which may be of any desired dimensions horizontally, but for convenience of treatment should not exceed five feet in height. Each load of manure on being added to the dump must be pressed down firmly with shovels, and if the weather be dry should be sprinkled slightly with water; finally the sides, which should be somewhat sloping, must be beaten and smoothed down with the shovel. . . ." It was found by Colonel Copeman that, four inches beneath the surface of a heap of fresh stable manure treated in this way, the heat produced by fermentation may be as much as 169° F., though housefly maggots are speedily killed at temperatures only slightly above 114.8° F. It should be noted that the fertilizing value of *close packed* is greater than that of loosely stacked manure.

"Although the success of close packing as a preventive of housefly breeding in horse-manure has been proved in England, the method has yet to be tested in warmer climates. In the event of failure from some unforeseen cause, the portion of the dump (both sides and top) in which maggots are seen should be covered over with a layer of sacking (old coal sacks, if without holes, answer well), soaked in heavy oil and secured by means of large stones; the sacking need only be allowed to remain for one week, after which if required it may be employed on another part of the dump."

The maggot trap.—It has already been explained that fly larvae respond to a migratory impulse just prior to pupation. The maggot trap (Fig. 110) takes advantage of this habit and consists of a wooden platform 20 feet long and 10 feet wide, supported on legs one foot high. Across the framework are nailed strips 10 feet long by one and one-fourth inches thick and one inch wide and one inch apart Slatted sides three feet high may be added to hold manure in place. This platform is placed in a concrete basin about four inches deep (concrete floor 22 feet long and 12 feet wide, with a rim four inches high and four inches thick), in which water is placed to a depth of one-half inch in the shallowest part. The basin floor is made to slope slightly toward one corner, which is fitted with a four-inch outlet pipe (plugged with wood when in use) so as easily to run off the water if necessary.

The manure is then dumped as usual directly from the stable upon the platform, with the precaution, however, that the manure must be sprinkled daily with enough water to moisten it thoroughly. Flies now deposit their eggs as usual and fly larvae develop to the point where they are ready to migrate, and because of the moist condition of the entire

pile leave it, drop into the water and are drowned. By the use of this method the Maryland State Agricultural Experiment Station reports a maggot destruction of 95.8 per cent for the three seasons 1914, 1915 and 1916. The close packing of the manure, the watering of the pile (using repeatedly the water in basin) and the return of leached materials to the manure tend to conserve the fertilizing value of the manure as already explained.

Chemical treatment of manure.—Athough there is a strong popular demand for some chemical which, if applied to the manure, will result in fly prevention, the writer is not enthusiastic about this method of control for several reasons; first, this scheme may be used as a substitute for the sound principle of sanitation, cleaning up and keeping clean, and second, owing to the necessity for daily application, there will certainly be neglect.

Ordinary applications of the usual insecticides are of little avail. The cheapest and at the same time the most effective preparations must be used two to five times as strong as when used against other insects because of the hardiness of fly larvae, and furthermore, the larvae cannot be reached easily, buried as they are in the bedding or manure. Broadly speaking, such chemicals may be either repellents to prevent flies from laying eggs on the manure, such as creosote oil; or they may be contact poisons, such as kerosene, chloride of lime and borax; or they may be stomach poisons, for both larvae and adults, such as arsenite of soda. From the practical standpoint, aside from their use in fly control, such chemicals should not impair the value of the manure as fertilizer. Furthermore, if poisons are used, the manure may be dangerous to livestock.

Many chemicals have been tried by a score or more of investigators and several chemicals have been found which can be used economically and effectively.

Borax is recommended by the United States Department of Agriculture at the rate of 0.62 pound to eight bushels of manure. In testing out the use of borax the New Jersey Experiment Station applied the following method:

eggs from hatching, provided it is applied in solution, and the larvae and eggs come in contact with it. It was figured out that the average output from one horse is one and one-half cubic feet of manure per day and that two and one-half gallons of water containing one and one-half ounces of borax should pene-

had been soaked by rains, or when located in low wet areas, was difficult to treat, for it was next to impossible to make any additional water (by sprinkling) penetrate the wet manure When manure is in this condition, particularly in low wet areas, and contains numerous larvae, it should be put on higher ground in order that it may dry out somewhat; or a thick layer of gravel or cinders placed under the manure in wet low areas will help considerably. Manure treated with borax is detrimental to some plants when the manure is used as a fertilizer, but, as far as known, it will not injure plants provided one does not use over 15 tons of treated manure (not over one pound of borax for every 16 cubic feet) to the acre"

Borax is an excellent chemical to use on dirt stable floors, in privies, and on accumulations of fermenting matter which will not be used as fertilizer.

Hellebore (the powdered roots of *Veratrum album* and *V. viride*) is *strongly recommended by the United States Department of Agriculture.* It is used at the rate of one-half pound to 10 gallons of water, applied after stirring and standing 24 hours, to 10 cubic feet or 10 bushels of manure. No injury to plants seems to result when treated manure has been used as fertilizer "The only possible objection to the use of hellebore seems to be the possibility of poisoning farm animals, as might happen if, for example, the barrel or tank in which the stock solution was prepared were left uncovered in an accessible place. It is quite safe to say that chickens will not be injured by pecking at hellebore-treated manure."

Creosote oil was used by the British during the World War in fly-control operations both on manures and on dead bodies. It was used at the rate of one gallon to the ton of manure and applied as a spray to each daily addition to the heap. It is said to be noninjurious to the fertilizing value of the manure, though this is doubtful. Creosote oil is also a good fly repellent when sprayed on beams, walls and floors of stables, or it may be applied to pieces of cloth and hung over entrances. It is said to have kept mess halls free from flies for from six to ten days.

Dust has considerable value in fly control. The writer found that

very few flies bred in the manure from cavalry horses on duty along the Mexican border during the summer time, when the droppings were thoroughly mixed with dust and disposed of in windrows a short distance from camp.

Use of manure on lawns.—It frequently happens that veritable swarms of flies suddenly make their appearance on porches, windows and in the house for no obvious reason. This is frequently due to the application of comparatively fresh manure to lawns. Such manure is commonly infested with full-grown maggots or pupae which, in a few days after the fertilizer has been applied, give rise to a pest of flies. It is, no doubt, wise to use old composted manure for this purpose or subject the manure to a thorough steaming or drenching with hot water at 195° F. (nearly boiling) before applying it to the lawn.

FIG. 111.—An effective combination garbage can and flytrap (After Hodge.)

Two objections are commonly raised against this method of treatment, first, that the useful bacteria are destroyed, i.e., the manure may be rendered sterile; and second, that all other desirable constituents are leached out by the water. Not all of the useful bacteria, by any means, are destroyed by the hot water, and those remaining quickly multiply and soon render the manure as good as ever in this respect. In the second place, the leachings may be preserved quite easily by placing the manure to be treated in a shallow, tight box similar to those used by plasterers for mixing mortar, and adding a spigot in a hole with plug from which the leachings can be drawn and used as liquid manure.

The above method is also useful to mushroom growers who must use rotted manure in which certain species of fly larvae, mites, etc., may occur in great numbers.

Railroad cars laden with manure are often sidetracked in or near communities and are responsible for swarms of flies. The writer has on several occasions recommended that the periphery of the entire carload be subjected to a treatment of live steam from the locomotive, with good results.

Garbage cans.—The writer has been favorably impressed with the type of combined garbage can and flytrap invented by C. F. Hodge. By his permission a diagram is here given (Fig. 111), together with his explanation of it (see Nature and Culture, July, 1911), as follows:

"The principle of operation is that hungry flies will crawl in toward the smell of food through any dark crack and, after feeding, will fly out toward the

light. They enter the garbage can or other receptacle by smell, and attempt to leave by sight. It is necessary to have the cover about half an inch larger in diameter. Three pieces of sheet iron are soldered inside the rim, equidistant apart, to hold it up, a crack, and keep it spaced out from the rim of the can about one-fourth of an inch all around. In a swill barrel, nails may be driven into the rim and bent over to hold the cover properly, *but direct light must not enter this crack.* Cut a hole in the cover at least three inches in diameter and fasten the trap over this opening according to plain directions sent out with each trap. With everything in the way of waste food material put into this receptacle, you establish a 'focus,' a 'vacuum cleaner' for flies, and properly managed this will prove exterminative."

Where ordinary garbage cans are used, and certainly every household should possess a garbage receptacle that can be tightly closed against flies (unless above plan is followed), it is strongly urged that all liquids be drained from the refuse before disposing of it and that the solids be wrapped in a newspaper before placing in the can. In this way fly breeding in garbage may be effectually prevented, and an act of mercy is done the scavenger and others as well.

Garbage collection and disposal.—Not only must the garbage can and its proper use be insisted upon in this connection, but also the proper collection of the garbage by the scavenger. Few sights are more disgusting than that of an open garbage wagon reeking with its load of vile-smelling offal and swarming with flies Municipal collection of garbage in properly constructed city-owned garbage wagons is the only solution of the present outrageous common system.

No more sanitary way of disposing of garbage can be devised than that of incineration The garbage *dump* will always be a fly producer, particularly if it receives manures and moist offal. Garbage disposal is a proper function of the sanitary engineer.

City dumps.—City dumps are very commonly the source of numerous flies. Flies were noticeably abundant in and about Newport News, Va , by May 1, 1918, and for the week ending May 25 it was reported that the restaurants were seriously infested by them and they were *numerous in all neighboring army camps. Camp Stuart particularly* was well within the range of flight of flies originating in and about the city, as within a distance of one-half mile of this camp the city of Newport News maintained a series of garbage dumps comprising a combined area of about five acres The dump in the vicinity of the gashouse extended for a distance of about one long city block on both sides of the street, nearly blocking it at several points. Near Boat Harbor the garbage extended to the street-car tracks. The "gashouse" dump not only received dead fish and all manner of perishable garbage, but also all the night soil from city privies, estimated at 900 at the time by the United States Public Health Service Flies swarmed over all, and mag-

gots beyond calculation pervaded the mass. The stench was indescribable.

The situation was soon remedied by liberally applying crude oil with spray pumps and setting fire to the dumps, which shrank little by little before the flames and fly breeding quickly ceased. Thereafter all dumping of garbage was done at certain points and incineration became the rule. The United States Public Health Service as rapidly as possible furnished sanitary privies, and the night soil systematically collected was emptied into the sewer.

Piggeries.—While on military duty at the Port of Embarkation, Newport News, Va., in 1918, the author observed a very severe outbreak of flies at the Embarkation Hospital. Although some fly breeding was discovered in several of the corrals, this was relatively unimportant; the real cause for the swarms of flies was discovered in a group of pigpens several hundred feet distant across an open narrow salt marsh. The owner of the swine collected the kitchen wastes, etc., from the hospital in such quantities that every available barrel, box, tub and pail was full and literally running over with swill and similar garbage These numerous receptacles, both inside and out, and the troughs and filth of the pens were literally infested with a creeping mass of maggots After the owner of these numerous broods of flies had been enlightened as to the nature of the maggots, he consented to any means of control necessary. The epidemic of flies was quickly checked by a combination of two methods: first, a detail of oilers from the Malaria Drainage Detachment was ordered to the piggery and liberal quantities of oil applied to every receptacle, including the ground beneath, and all the pens, resulting in a great slaughter of maggots; and secondly, numerous saucers containing a mixture of formaldehyde, canned milk and water (formalin one pint, canned milk one can, sugar one pound, water three gallons) were placed in front of the wards with the result that the ground in the immediate vicinity of the saucers was soon black with dead flies. The fly epidemic was quickly checked. This experience led to a more careful survey of similar conditions, with the result that over 50 pigpens were found to be within a distance corresponding to about two city blocks and easily within a half mile of Camp Stuart. These pens were all in an indescribably filthy condition and literally alive with flies and maggots

The addition of a small quantity of turpentine to the swill serves to repel flies to a certain extent and thus limits breeding; however, the writer has found that much of the fly breeding in piggeries is due to slops and feed in general being pushed out of the troughs and accumulating around them, thus forming an excellent fly pabulum, a mixture of hog manure, slop and urine. The liberal use of concrete for floors, troughs and wallows and frequent flushing out with a hose will greatly reduce the crop

of flies which one usually encounters at a piggery during the summer time.

Dairies.—The presence of numerous flies about the premises of a certified dairy, which upon inspection was found to be very clean and otherwise in excellent condition with no evident reason for the presence of the flies, was a matter of no small importance under the circumstances. The trouble was located in a field a few hundred feet from the dairy barn where numerous heaps of waste brewer's grain (used as cattle feed during late summer and autumn) had been hauled and dumped. Each heap was a veritable wriggling mass of housefly maggots. Liberal applications of fuel oil to the heaps soon destroyed the source, and further waste feed was spread out in a thin layer to facilitate rapid drying and thus to defeat fly breeding. The epidemic of flies was soon brought under control. Fly breeding about dairies is frequently traceable to accumulations of waste feed about the troughs, the waste becoming mixed with feces and urine. Thus bad conditions may arise in spite of the proper disposal of manure.

Lawn clippings.—Grass clippings from lawns around public buildings are often dumped in heaps near by. Hot weather soon produces a vile-smelling, decomposing, hot mass of grass which is very attractive to flies and within a few days numerous maggots, particularly those of the housefly, may be found inhabiting the mass. Thus, again, in spite of the absence of manure and garbage there may be a veritable plague of flies The method of control is obvious; namely, the clippings should be spread out thinly in order to dry out, and they may then be burned or otherwise disposed of.

Flies from septic tanks.—A smaller invasion of flies at one of the Embarkation Hospital wards noted above was traced to a near-by septic tank which was covered with a wood superstructure. Workmen in making certain changes had left two or three circular openings about six or seven inches in diameter. Numerous flies were coming and going through these apertures, and *examination of the top sludge revealed countless* maggots and pupae on the surface where there was less moisture. Closing these apertures and spraying the contents as a matter of precaution in spots only where the larvae and pupae occurred soon ended the trouble An examination of other septic tanks in other camps showed similar conditions, where poor construction of the wood superstructures left crevices and knotholes which provided a means of entrance and exit for flies

Sewage treatment plants.—Flies of many species, notably the common housefly and blow flies, may be attracted to sewage treatment plants because of odors, and often countless numbers of these flies originate in sludge beds at the end of the treatment process There may also be much

fly breeding in wet sludge when applied to the soil as a fertilizer. The control of the latter source may be accomplished by deep plowing and, of course, discontinuance of the use of wet sludge as a fertilizer. Unless attention is given to proper sludge disposal fly breeding will prevail.

Sewage treatment plants of modern construction do not as a rule breed flies. However, under all circumstances raw sewage must not be accessible to flies because of possible portage of pathogenic organisms of fecal origin. Sewage-works engineers suggest that fly breeding may be effectively prevented by quick drying of sludge. Chemical treatment of sludge is not generally favored, although spraying screenings with a solution made of one and a half pounds of pure carbolic acid and 40

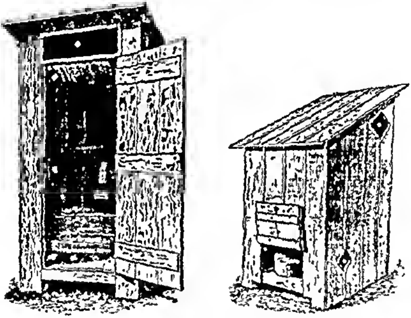

FIG 112.—A sanitary privy—front view to left; rear and side view to right. (After Stiles and Lumsden.)

pounds of caustic soda in 60 gallons of water has been effectively used to stop fly breeding.

The sanitary privy.—In the absence of modern plumbing particular attention should be paid to the location and construction of a box privy with receptacle or dug pit. No doubt much typhoid fever, diarrhea and dysentery are traceable to insanitary privies. Two important matters are involved; namely, first, location so as to avert pollution of wells or other water supply; and second, construction so as to prevent flies from gaining access to the excreta and to insure privacy.

A sanitary privy (Fig. 112) must meet the following requirements, according to the United States Department of Agriculture (Farmers' Bulletin 463—Stiles and Lumsden):

"(1) The excreta must not touch the ground; hence some kind of watertight receptacle (box, pail, tub, barrel, tank or vault) for the excreta must be used under the seat. (2) Domesticated animals must not have access to the night soil; therefore the privy should have a trapdoor in the back to exclude them. (3) Flies and other insects must not have access to the excreta; therefore the entire privy must be made rigidly flyproof, or some substance must be used in the receptacle to protect the contents from insects."

Where the excreta are deposited in a pit or cesspool great care must be exercised in banking up around the outside of the building so as to prevent flies from gaining access to the pit. Furthermore, it may become necessary to apply quantities of chloride of lime, crude oil, kerosene, or borax to the excreta at least twice a week during fly time.

If the privy is built on skids or can be otherwise easily moved, in addition to the treatment mentioned above, the accumulated excreta should be burned from time to time by adding straw and crude oil and setting them aflame. If sufficient water is available, the country home should be provided with modern sanitary plumbing, and a septic tank should be installed to receive the sewage

Flytraps.—Unless flytraps are used to capture the flies as they emerge from their breeding places, as already described, such measures are ordinarily only excuses for failing to observe the more important cleaning-up process; the entrapped flies have ordinarily already had ample opportunity to carry filth and germs and deposit their eggs However, traps may be useful adjuncts to other more permanent corrective measures—the more flies captured and swatted, the better—but the trapping and swatting should begin early in the spring in order to capture the early flies which are responsible for the later multiplied millions of the same species

Furthermore, flytraps may be attached to garbage cans (Fig. 111), manure bins, etc , as already described so as to capture flies as they emerge from their breeding places. In the first case the traps must be properly baited, while in the second case the flies simply enter the traps, going from the dark bin or can to the aperture over which the trap is placed, i e , flies go toward the light.

Many different styles of flytraps are on the market and homemade traps are easily made, the principal factor is the bait—no trap will work unless it is properly baited

It has been found that one of the most effective baits for houseflies is made of blackstrap molasses, one part, mixed with three parts of water, allowed to stand for two or three days Another attractive bait is made of a mixture of bran, mashed potatoes, sugar, yeast and water, or simply bran mash made quite thin with sour milk and sweetened with brown sugar Stale beer, a mixture of sugar and vinegar and water, blood

taakage, fish scraps, juice of crabs, etc., all have value as bait. Bait should be placed in *large* shallow pans and should be frequently renewed.

Fly poisons.—There are many kinds of fly poisons in use, notably the proprietary cobalt and arsenical solutions. There is considerable danger in the use of many of these, as shown by numerous newspaper accounts reporting deaths of children traceable to drinking fly poisons. A very good substitute for such poisons is to be found in *formaldehyde* (formalin). This chemical may be purchased commercially in a 38 to 40 per cent solution and must be greatly diluted for use as a fly poison. The commercial 38 to 40 per cent solution is poisonous like wood alcohol, if taken *internally*, hence must be handled accordingly. However, when diluted to a strength of 1½ to 2 per cent ready for use, it is comparatively safe. For household use two or three teaspoonfuls of the *concentrated* (38 to 40 per cent) formaldehyde is used to a pint of a mixture of water and milk in about equal proportions (canned milk is excellent and much less is necessary), with a small quantity of sugar or molasses added to sweeten. On a larger scale the quantities are as follows: formaldehyde, one pint; canned milk, one pint; sugar, one pound; water, three gallons.

The preparation is used as follows: place a small piece of bread (or even a small sponge) in a shallow vessel, such as a saucer or tin plate, and pour over it enough of the mixture to saturate the bread and leave some of the liquid about in the plate. Then place the receptacle where there are most flies. Flies which drink the solution are killed in the course of a few minutes and will be found scattered about near by. The liquid must be replenished frequently.

Sodium salicylate at the rate of three tablespoonfuls of the pure chemical (a powder) to a pint of water may be used in the same manner as the formaldehyde solution with similar good results.

Sticky flypapers may be more of a nuisance than anything else, but if properly handled serve a good purpose. A good plan is to prepare a flypaper board. Take a one-half inch to seven-eighths inch board 10 by 14 inches long and nail a strip of two-inch light board along the 14-inch edge so that it extends for a short distance on either side, producing an inverted letter T as viewed from the end. One-half inch from the upper edge of the board and near each end bore a hole, so as to suspend it by strings passed through the holes. Tack sheets of sticky flypaper on both sides of the board, so that the drippings will fall upon the lower board.

Sticky flypaper may be made as follows, according to the Kansas State Board of Health: "Take two pounds of rosin and one pint of castor oil; heat together until it looks like molasses. Take an ordinary paint brush and smear while hot on any kind of paper; an old newspaper is good."

Natural enemies.—The most important natural enemy of the house-fly is the fly fungus, *Empusa muscae* Cohn, first described by DeGeer in 1872 (Howard), and rediscovered annually by enthusiastic human enemies of the housefly. During late summer and autumn and throughout the moist winter in California, dead flies are frequently found clinging to curtains and walls; the abdomen is usually greatly distended, showing distinct bands due to the appearance of intersegmental tissue brought to view by the pressing apart of the darker segmental rings. The disease is commonly known as fly cholera.

This fly fungus originates from spores which, when a fly is attacked, produce hyphae, thread-like processes which enter the body of the fly and develop a meshwork of threads, producing great distension of the fly's abdomen. This mycelium later evidently sends out hyphae through the intersegmental tissue, which hyphae then produce spores or conidia. The spores are then separated often with some force, and may produce a sort of "halo" about the now dead fly. Other flies thus become easily infected. The writer has lost experimental colonies of flies in great numbers in this way in less than two weeks after the appearance of the disease.

Another very common parasite of the fly is a red mite, *Acarus muscarum* Linn. Often several of these mites may be seen as tiny red specks on the head, neck or thorax of the housefly. Occasionally they actually retard the fly in its flight.

When rearing houseflies from pupae collected out of doors, one is frequently surprised to find that 50 per cent or more give rise to a tiny dark metallic wasp which creeps out of the pupa case through a minute hole. These are chalcidoid wasps, one species of which is known as *Nasonia brevicornis* Gir. and Sand.

While houseflies are also attacked by various other natural enemies, such as spiders, robber flies, toads, lizards, etc., their generation does not seem to be greatly affected, and man must depend more and more on suppressing the breeding places of these pests or suffer the consequences.

CHAPTER XVII

BLOODSUCKING MUSCIDS

(*Tsetse Flies, Stable Flies, Horn Flies*)

ORDER DIPTERA—FAMILY MUSCIDAE

A. TSETSE FLIES

Introduction.—The genus *Glossina*, which comprises the tsetse flies, was established in 1830 by Wiedemann, and in the same year Robineau-Desvoidy described *Glossina palpalis*. Bequaert[1] states that the word "tsetse" was introduced into the English language by R. Gordon Cumming in 1850 in his "Five Years of a Hunter's Life in the Far Interior of South Africa," and David Livingstone in 1857 "focussed the attention of the scientific world upon the ravages of the fly."

That the tsetse flies enjoyed a wider distribution in geological times is evidenced by the fact that several very large species of fossil *Glossina* flies from the Miocene shales of Colorado have been described. Today the tsetse flies are restricted to continental Africa south of the Tropic of Cancer except for one species, *Glossina tachinoides* Westwood, which is said to occur also in southwestern Arabia, thus exhibiting an example of discontinuous distribution.

Tsetse flies (Fig. 113) of both sexes depend on blood for sustenance and feed on a wide variety of animals, although different preferences are shown by the different species of tsetses; while freely attacked, man is not considered to be a favored host. *Glossina morsitans* Westwood feeds mainly on game animals, the buffalo being highly favored, while *Glossina palpalis* (Robineau-Desvoidy) and *G. tachinoides* Westwood favor reptiles, particularly crocodiles and monitor lizards.

Students concerned with tsetse flies will consult such highly important works as Austen and Hegh[2] (1922), Newstead[3] (1924), Hegh[4] (1929) and particularly Swynnerton[5] (1936), as well as the work of various other authors published in the several technical journals.

General characteristics.—The tsetses are medium-sized to moderately large flies, ranging in size from that of a housefly to that of a blowfly. The larvae are ready to pupate when born. The flies are brownish in color; the body is wasp-like and the wings when at rest are crossed scissors-like and extend well beyond the tip of the abdomen. The wing

venation is characteristic in that the fourth longitudinal vein (M_{1+2}) bends suddenly upward before it meets the anterior transverse vein, which is very oblique (Fig. 58).

The palpi are nearly as long as the proboscis which points bayonet-like in front of the head. The antennal arista (Fig. 114) bears a series of long bilaterally branched and regularly arranged hairs only on the upper surface. Grünberg [6] attached taxonomic value to the aristal hairs.

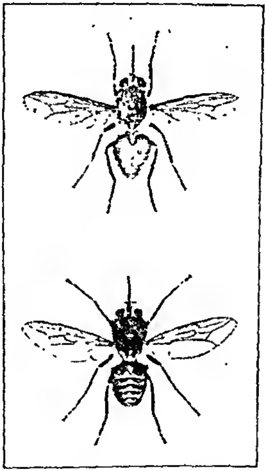

FIG 113 — *Glossina palpalis* (top), *Glossina morsitans* (bottom) (After Newstead)

The mouth parts consist of the labium which ensheathes the two slender piercing stylets, the labrum-epipharynx and the hypopharynx. A characteristic "onion-shaped" bulb is situated at the base of the haustellum (Fig 115) The proboscis when at rest is held like a bayonet at charge as in *Stomoxys*. Both sexes are bloodsuckers.

Life history.— The female tsetse fly gives birth to full-grown larvae which are extruded singly at intervals of about 10 to 12 days during the

Nabarro[11] proved *Glossina palpalis* (R.-D.) to be the carrier by feeding freshly caught flies ranging in number from 31 to 9 on a black-faced monkey daily, sometimes twice daily, beginning May 13. Trypanosomes were present in the blood May 27. In 1903 Castellani[12] reported trypanosomes in the cerebrospinal fluid of negroes in Uganda suffering from sleeping sickness. The trypanosomes found by Castellani were supposed to be a different species from that of Dutton (*Trypanosoma gambiense* Dutton) and were called *T. ugandense* Castellani, 1903. Kruse later gave to this trypanosome the name *T. castellanii*. The important discoveries of Dutton and Castellani were quickly confirmed by David Bruce, who found these trypanosomes 38 times out of 38 in the cerebrospinal fluid obtained by a lumbar puncture in natives of Uganda suffering from sleeping sickness, and 12 times out of 13 in the blood. According to the rules of priority applied to nomenclature, the last two specific names mentioned must give way to *Trypanosoma gambiense* Dutton. A second species of trypanosome producing sleeping sickness in Rhodesia, Nyasaland, and adjoining territory was described in 1913 by Stephens and Fantham (loc. cit.) as *T. rhodesiense*.

Sleeping sickness is widely distributed in Africa, extending along the west coast from Senegal (in part) to Angola (in part) and eastward to the valley of the upper Nile. It has been estimated that between 1896 and 1906 from 400,000 to 500,000 natives perished from this pestilence. Dutton and Todd found that in some villages from 30 per cent to 50 per cent of the population was infected.

Age does not affect the distribution of the malady, since children as young as eighteen months to two years have been known to be infected. Sex does not influence the disease. Occupation and social position, however, do show a marked influence. The great majority of the cases observed are among the agricultural and lower classes.

There are two distinct phases in sleeping sickness. During the first phase, which may continue for many months, the trypanosomes are in the blood, the trypanosomiasis stage; this is characterized by an irregular fever, glandular enlargement, debility, and languor. In the second phase, the sleeping sickness stage, the trypanosomes are constantly found [illegible] languor and [illegible] o [illegible] s [illegible] e of sleeping sickness recognized, the Gambian and the Rhodesian [illegible] latter runs a more rapid course than the former.

Transmission.—The natives of French Guinea long attributed the power of disseminating sleeping sickness to flies, and it had already been shown by Bruce that nagana, a disease of cattle and horses, was transmitted by tsetse flies when Dutton and Todd studied the biting *flies of*

Gambia. These investigators found that of the flies which bite man and animals, *Tobanus dorsovittata* Walker and *Glossina palpalis* (R.-D.) were the most important, the latter being very common in western Africa, where it abounds in the mangroves which line the rivers and water banks during the warmer months when these insects are very troublesome.

Experiments, however, made by these workers gave negative results. It was Bruce and his collaborators (loc. cit.) who subsequently went over the matter and showed that *Glossina palpalis* (R.-D.) is the principal agent of transmission.

Animal experimentation indicates that these flies can transmit the causative protozoön mechanically for a period of less than 48 hours, though the organisms become more and more attenuated after the fly has bitten the diseased individual and loses its power of infection in less than 48 hours. Thus the tsetse fly is a mechanical carrier for only a few hours during which time its soiled proboscis is involved, i.e., trypanosomes are injected into the wound produced by the bite before the proboscis is cleaned. Mechanical transmission from man to man in nature is believed to be very uncommon, if it occurs at all.

Robertson [12] reports that in the fly the trypanosomes are first established in the posterior part of the mid-gut where multiplication occurs and trypanosomes of varying sizes are produced. From the tenth or twelfth day onwards slender, long forms are to be found in increasing numbers. These finally move forward to the proventriculus and are the dominant type. The proventriculus becomes infected as a rule between the twelfth and twentieth days. The salivary glands become infected by the slender proventricular types which reach the glands by way of the hypopharynx, arriving in the glands, they become attached to the wall and assume the crithidial condition. Multiplication takes place and trypanosomes are formed which closely resemble the blood type. The development in the salivary glands takes from two to five days before the forms are infective. The fly is never infective until the glands are invaded. The trypanosomes are never attached to the wall of the alimentary canal, and there is no intracellular multiplication in the gut cycle. Miss Robertson's work was done with *Trypanosoma gambiense* Dutton in *Glossina palpalis* (R.-D.). The Sleeping Sickness Commission has found that infectivity lasts at least ninety-six days. The life of a female *G. palpalis* (R.-D.) in captivity has been observed to be about four and one-half months.

The problem of sleeping sickness is greatly complicated in that many species of game animals as well as reptiles harbor the trypanosomes and thus serve as natural reservoirs of the infection.

Glossina palpalis (R.-D.) (Fig. 113) is the most important vector of Gambian sleeping sickness. It covers an enormous area in Africa, but it

occurs chiefly in the Congo and in west Africa. It is usually found on the shores of rivers and lakes, but it may occur quite far back from them, and as Swynnerton points out, it requires a combination of several types of country one of which must be relatively massive wooding or thicket of more or less evergreen type. It lives mainly on reptiles, but can live on mammals as well. Man is not regarded as one of its favored hosts, although it will feed on him freely if sufficiently hungry.

Glossina morsitans Westwood (Fig. 113) is a most efficient vector of both Rhodesian sleeping sickness of man and nagana of animals. It has a wide distribution in Africa; it is of importance in the Sudan, northern and southern Rhodesia, the Belgian Congo, and many other localities. This species requires "savanna of sufficient shade value, and with sufficient logs, rocks, or tree rot holes to form a good rest-haunt and breeding-ground, and relatively open glades or plains in which to hunt for its prey." It is typically a "game fly," but attacks human beings readily, hence is a most dangerous tsetse.

Glossina swynnertoni Austen, like *G. morsitans* West., is a strong vector of both Rhodesian sleeping sickness and nagana. It is largely confined to the northern part of Tanganyika, according to Swynnerton, who describes it as "the fly of the driest and most open areas and apparently unable to inhabit the more mesophytic savannas. It breeds normally in thicket, though rock suits it as well. . . . It utilizes open spaces as feeding grounds. . . . It is primarily and essentially a 'game' fly." It attacks human beings with readiness, and like *Glossina morsitans* West. is a very dangerous tsetse.

Nagana.—Trypanosoma brucei Plimm. and Bradf. is the causative organism of nagana, early known as the fatal tsetse-fly disease of African horses, mules, and camels, less rapidly fatal to cattle, sheep, and dogs. Many other mammals are susceptible to the infection. Bruce (loc. cit.) found that many species of wild game animals harbor the trypanosome and thus form reservoirs. The disease is characterized by progressive emaciation, fever, edema of the abdomen and genitalia and marked depression. The trypanosomes are found in the blood and especially the lymph-gland swellings from the beginning of the first symptoms.

Glossina morsitans West., *G longipalpis* (Wied.), *G. pallidipes* Austen, *G. tachinoides* West., and *G. austeni* Newstead, relate to its transmission in practically the same way that *Glossina palpalis* (R.-D.) and other *Glossina* flies relate to sleeping sickness of man, i.e., the flies are infective for a day or two after feeding on an infected animal, then become non-infective for a period of about three weeks when they again become infective, remaining so for the rest of life. The incubation period after inoculation into the body of the host is said to be about ten days.

Tsetse fly control.—Since the memorable discoveries of Bruce and others that tsetse flies are responsible for the transmission of nagana and sleeping sickness, few insects have been so minutely studied by the most capable investigators. The practical and extended control of breeding places offers serious difficulties; not the least of these being the fact that the larvae are retained within the body of the female, hence are not directly dependent upon an external food supply. The monumental work of the late C. F. M. Swynnerton gives ample testimony to the tremendous ramifications of the tsetse fly control problem. Among the many possible modes of attack there are the following: (a) direct attack, involving the use of flytraps; the direct effect of temperature and moisture on pupae; the use of natural enemies, etc.; (b) indirect attack by modification of cover, reducing or expelling game animals, thus depriving the flies of food supply; fly barriers by setting up clearings or thickets according to the species of fly to be dealt with; reclamation and appropriate agricultural practice.

Because of the wide divergence in the ecological requirements of the several important species of tsetse flies, the utilization of appropriate control measures is a matter of long and tedious investigation.

Classification.—Newstead (loc. cit.) recognizes twenty species, one subspecies and five varieties belonging to the genus *Glossina*. These he divides into three groups, (1) the *fusca* group, which includes the ten largest species, viz , *Glossina brevipalpis* Newstead, *G. fusca* (Walker), *G. fusca* var. *congolensis* Newst. and Evans, *G. fuscipleuris* Aust., *G. haningtoni* Newst. and Evans, *G. longipennis* Corti, *G. medicorum* Aust., *G. nigrofusca* Newst., *G. schwetzi* Newst. and Evans, *G. severini* Newst., and *G. tabaniformis* West.; (2) the *palpalis* group, which includes *Glossina caliginea* Aust., *G. pallicera* Bigot, *G. palpalis* (Rob.-Desv.) and two varieties, var. *wellmani* Austen and var. *maculata* Newst., also one subspecies *G. palpalis* subspecies *fuscipes* Newst., and *G. tachinoides* West.; (3) the *morsitans* group, which comprises *Glossina longipalpis* (Wied.), *G. morsitans* West., *G. morsitans* var. *pallida* Shirc., *G. morsitans* var. *paradoxa* Shirc., *G. submorsitans* Newst., *G. pallidipes* Aust., *G. swynnertoni* Aust., and *G austeni* Newst.

B. Stomoxys Flies

Family Muscidae, Genus Stomoxys

General characteristics.—Owing to similarity in color and size the stomoxys fly is often mistaken for the common housefly *Musca domestica* Linn However, the former is more robust with broader abdomen. In color it is brownish gray with a greenish yellow sheen; the outer of the four longitudinal thoracic stripes are broken and the abdomen is more or

less checkered. The wings when at rest are widely spread apart at the *tips, are distinctly iridescent* and the apical cell is open. When resting the fly has its head thrown well up and the wings slope decidedly toward the surface upon which it has settled. The proboscis protrudes bayonet-like in front of the head. The antennal aristae, unlike those of the housefly, bear setae on the upper side only. *Stomoxys calcitrans* (Linn.) enjoys practically a world-wide distribution.

Habits.—Although the stomoxys fly, *Stomoxys calcitrans* (Linn.), is commonly called the "stable fly," it occurs much less abundantly (is

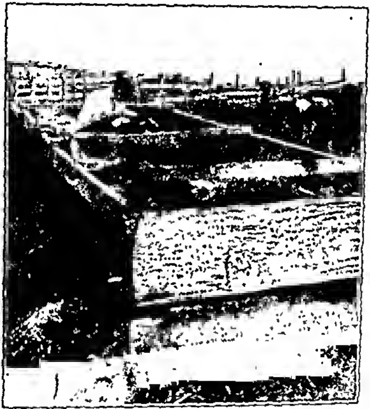

FIG. 117.—Feed racks for dairy cattle which furnish an ideal breeding place for stomoxys flies. The moist lower layers of material in the trough furnish abundant food for the larvae.

often absent) about stables than does the housefly. It is also called the "biting housefly," since it may occur indoors, especially in the autumn and during rainy weather, and bites human beings viciously. The stomoxys fly is typically an out-of-door fly and is usually to be found in abundance during summer and autumn where domesticated animals occur, especially cattle. Its occurrence around stables is for feeding purposes, i.e., sucking blood from cattle, horses, and other animals. Sunny fences, walls, light-colored canvas coverings and light objects in general when in the proximity of cattle are abundantly frequented by stomoxys flies.

The stomoxys fly is a vicious "biter," draws blood quickly and fills up to full capacity in from three to four minutes if undisturbed, but ordinarily even when undisturbed changes position frequently or flies to another animal, where the meal is continued. This fly feeds readily on many species of warm-blooded animals, for example, rats, guinea pigs, rabbits, monkeys, cattle, horses and man. Both sexes are bloodsucking. The flight of the stomoxys fly is direct and swift.

Breeding habits and life history.—Although the stomoxys fly can successfully be reared in the manures of horses, cattle, sheep, etc., it may be safely said that it does not breed commonly in excrement under field conditions unless well mixed with straw or hay. Very good breeding places are afforded by the leftover hay, alfalfa or grain, in the bottoms of, or underneath out-of-door feed racks (Fig. 117) in connection with dairies. This material becomes soggy and ferments, and here practically pure cultures of stomoxys larvae may be found. The material must be moist; dryness prevents development. Piles of moist fermenting weeds and lawn cuttings also furnish fairly good breeding material. Piles of decaying onions have been found by the writer to harbor myriads of larvae late in autumn. Old straw piles that remain in the field in all weather may produce an abundance of stable flies in the moist fermenting straw near the ground, particularly if cattle have access to the straw and moisten it with urine.

The larvae of stomoxys and of the housefly can readily be differentiated by the form, size and position of the posterior spiracles, otherwise they resemble each other closely. The pair of posterior spiracles of the stomoxys larva are roughly triangular, widely separated and situated near the periphery, while in the housefly larva they are elliptical, quite large, close together and more central in position. (Fig. 122.)

The eggs of the stomoxys fly are about 1 mm. long, curved on one side, straight and grooved on the opposite side. In depositing her eggs the female fly often crawls far into the loose material, placing them usually in little pockets in small numbers, often in pairs. Egg depositions range in number from 23 to 102, usually between 25 and 50, and there are ordinarily four or five layings. Mayne (Mitzmain [14]) has found in his observations made in the Philippine Islands that the maximum number of eggs produced by a single stomoxys is 632 and possibly 820, and that there may be as many as twenty depositions during the lifetime of the female.

The incubation period varies from two to five days, commonly three days, at a temperature of 26° C. Higher temperatures result in a shorter incubation period. The newly hatched larvae bury themselves in their food at once, thus protecting themselves against light and dryness. At a temperature of from 21° to 26° C., the larvae reach full growth in from

14 to 26 days. Mayne found that the larval stage averaged 12 days at a room temperature of 30° to 31° C.

Before pupation the larvae usually crawl into the drier layers of the breeding material, where the chestnut-colored pupae are often found in enormous numbers. The pupae are from 6 to 7 mm. long and may be recognized by the posterior spiracles as in the larva. The pupal period also varies, dependent largely on temperature. At a temperature of from 21° to 26° C., this period varies from 6 to 26 days, with the greatest frequency between 9 days and 13 days.

At an average temperature of 29° C., Mayne found the pupal period to average five days.

If not handicapped, the imago emerges with astonishing rapidity, crawls away, unfolds its wings and is ready to fly away in less than half an hour. The fact that the proboscis is temporarily attached beneath the thorax gives the newly emerged insect a very peculiar appearance, and it may then be easily mistaken for a housefly.

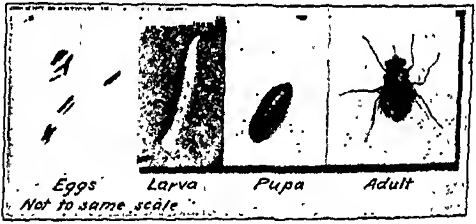

FIG. 118.—Showing the life history of the stable fly, *Stomoxys calcitrans*. (Photo by H. F. Gray.) × 2.

Summarizing the life history of the stomoxys fly (Fig. 118) it may be said that at a temperature of 21° to 26° C., the *shortest* periods are: egg, 2 days; larva, 14 days; pupa, 6 days; total, 22 days; the *average*, egg, 3 days; larva, 15 days; pupa, 10 days; total, 28 days; the *maximum*, egg, 5 days; larva, 26 days; pupa, 26 days; total, 57 days. The total time at 21° C., from the laying of the egg to the emergence of the adults, was from 33 days to 36 days as observed in five individual cases. Mayne reports the development of this fly in 12 days under optimum conditions.

Copulation takes place within a week and egg deposition begins in about 18 days after emergence from the pupa cases at a temperature of from 21° to 26° C. Higher temperatures undoubtedly decrease this time.

Longevity.—With approximately 4,000 flies under continuous daily observation in glass quart jars, 50 flies to a set, the writer has found that the average length of life of the stomoxys fly under favorable laboratory conditions of feeding (i.e., daily feedings on monkeys or rabbits) is about 20 days. The maximum life under these conditions was found to be 69 days and several hours—observed in a female.

Mayne has found the maximum for a female fly to be 72 days and for the male 94 days.

The writer has observed that a set of flies which fed only on sugar water deposited no eggs, although many of them lived 20 days or longer, while control flies fed on blood did lay eggs. Hence it seems apparent that the flies must have blood in order to develop eggs.

As a cattle pest.—Bishopp[13] regards this fly as one of the most important sources of annoyance to livestock. Injury is brought about in various ways, e g, worry due to the attacks of myriads of flies; loss of blood; loss of flesh; bringing on of attacks of acute Texas fever if the cattle are already parasitized, etc.

Freeborn, Regan and Folger[16] have shown that the reduction in milk production caused by the stable fly amounted to 9 26 per cent, which for a five months' period meant a loss of 50 gallons of milk, amounting to ten dollars per cow per season. The total loss occasioned by the three dairy cattle pests, houseflies, stable flies and horseflies, amounted to 14 per cent.

Poliomyelitis.—The possibility of insect transmission of infantile paralysis has long been recognized, but never satisfactorily proved. The following is quoted from a report of Rosenau's work in the Journal of the American Medical Association (Vol LIX, 1912, No 14, p 1314) under "Proceedings of the International Congress on Hygiene and Demography."

"When I first began to study the disease, I regarded it probably as one which is spread by direct contagion, by contact, either directly or indirectly, from person to person. The first circumstance which shook my faith that we were dealing with a contagious disease was the fact that we had eighteen negative results in attempting to prove the presence of the virus in the secretions from the nose and throat I could not help asking at the time if it were not possible to find the virus, which is so potent, in the secretions of the nose and throat of persons who have the disease and those who are convalescing from the disease. These results were confirmed at the same time by Strauss, of New York, who had negative results in a large series and by Neustaedter's recent results and by other results, all of the examinations having proven negative excepting one recently reported by Kline, Patterson and his associates at this congress and in the literature recently.

"A second circumstance which led me to believe we were not dealing with a contagious disease was the fact brought out by Dr Richardson Children in all stages of this disease were crowded into schools, institutions, tenement districts and other places where there was every chance for the spread of the dis-

ease, but it did not spread there, but it continued to spread in the rural, thinly scattered districts where one would not expect to find contagious disease. There was a resemblance to rabies. All those who have worked with this virus in laboratories were at once struck with the resemblance between poliomyelitis and rabies. The latter being a wound infection, there is some analogy between it and poliomyelitis, and poliomyelitis might be transmitted through some sort of wound. I was fortunate enough to have had experience with yellow fever, both in the investigation of it and the sanitary measures against it, before the mosquito period, and I was much struck with many analogies which came to me between that disease and certain features of poliomyelitis.

"The work I bring to your attention consisted of taking a number of flies —*Stomoxys calcitrans*—caught in a net and bred for the purpose; you can catch several hundred of these flies in a stable in a very short time. We placed these flies in a large cage and exposed monkeys to their bites, the monkeys having been purposely infected with the virus of poliomyelitis Care was taken to place the monkeys in the cages in all stages of the disease, before and after. In fact, a monkey would be exposed to the bites of the flies on the same day he was infected, so that the flies could drink the blood of the monkey during all stages of the period of incubation of the disease, for we do not yet know in what stage of the infection the virus appears in the blood at its maximum, or the best period for infecting these flies. Following this we exposed healthy monkeys to the bites of the same flies, and after several weeks' time these healthy monkeys came down with a disease which in all essential respects resembles anterior poliomyelitis. Out of twelve healthy monkeys so exposed, six of them now have symptoms of the disease, three of them in the virulent form. Of the other three monkeys, two are coming down, but one seems to have a milder infection than the other. This mild infection consists of trembling and weakness of the hand, and some weakness of the jaw which lasted about a week or so and then passed away. We cannot be sure whether that is true poliomyelitis or not until we are able to test the monkey subsequently. If it were poliomyelitis, that monkey would be 'immune.' In three of the six cases that came down with the disease, having been bitten by flies, there was some diarrhea. The disease in the monkey resembles more closely that which we see in children, rather than the disease we produce purposely experimentally by bringing the virus in direct association with the central nervous system. Of course, that may be only a coincidence, but it is interesting."

The work of Rosenau was repeated and confirmed during October, 1912, by Anderson and Frost [17, 18] who summarize as follows: "Three monkeys exposed daily to the bite of several hundred stomoxys, which at the same time were allowed daily to bite two intracerebrally inoculated monkeys, developed quite typical symptoms of poliomyelitis eight, seven and nine days from the date of their first exposure."

In order to verify the findings of the above investigators and to secure further biological evidence, if possible, the author in coöperation with Dr. W. A. Sawyer,[19] undertook a special investigation of the problem, beginning in October, 1912. Believing it unwise to use flies collected out of doors, these insects were reared for the purpose in an insectary. The importance of this precaution is made evident by the fact that flies cap-

tured out of doors in Berkeley were shown to transmit a pathogenic organism to a rabbit, infection undoubtedly having been acquired in nature. This infection, resulting in abscess, was successfully transmitted from rabbit to rabbit through the agency of the stomoxys fly.

"In Rosenau's announcement he stated that the monkeys showed symptoms of poliomyelitis several weeks after the flies, which were biting them frequently, had had their first opportunity to receive infection from sick monkeys. This would allow abundant time for a definite biological change in the virus, preparing it, during the incubation in the fly as intermediate host, for successful inoculation into the warm-blooded monkey. Such a process seemed not an improbable explanation of the results when we considered that Rosenau was dealing with a blood-sucking insect and a disease in which the blood had been shown to have very low infectivity on direct inoculation. The symptoms of poliomyelitis in the experiments of Anderson and Frost appeared so soon after the first possible transference of infectious material that in all probability the process consisted of a mechanical transference of blood or other infectious material taken up by the flies while repeatedly piercing the skin. The extreme shortness of time available, in their experiments, for incubation of the virus in the fly is apparent when we consider that, in the interval of nine or ten days, we must allow also for the development of the virus in the original inoculated monkeys and for the incubation period in the monkeys infected by the flies" (Sawyer and Herms, loc. cit.)

Assuming the accuracy of the work of Rosenau and Anderson and Frost, it seemed advisable to plan the experiments so as to secure, if possible, an answer sooner or later to each of the following questions:

1. Is the stomoxys fly merely a mechanical carrier of poliomyelitis or is it an intermediary host?
2. If it is an intermediate host how much time must elapse after biting before it can infect another animal?
3. How long does the fly remain infective?
4. How soon after infection does the experimental animal become infective to the fly and how long does the animal remain infective to the fly?
5. Does the severity of the infection increase with the number of bites of the fly?
6. What is the percentage of infected flies in nature?
7. Do other biting insects carry this disease?
8. Can other animals be inoculated by the stomoxys fly and serve as carriers or receptacles of the disease, e.g., chickens, rabbits, guinea pigs, rats, mice, pigs, dogs, cats, horses and cattle?
9. What are the best methods to exterminate the stomoxys fly?
10. What precautions are necessary to prevent the existing flies from coming in contact with infectious patients and carrying the disease to other individuals?

A series of seven experiments was conducted covering a period of about nine months and involving the use of about four thousand laboratory-reared flies, a large number of monkeys, rabbits and other rodents.

The experiments were carefully planned and every precaution was taken to bring about accurate results. In the first experiment approximately 1,750 flies were used, applying these to the animals in bobbinet-covered glass jars (quarts), 50 flies to a set (Fig. 119). A rhesus monkey was inoculated intracerebrally with 2 c.c. of a suspension of Flexner virus, and the first set of flies was placed on this animal immediately after inoculation and after ten minutes' feeding transferred to a healthy monkey. The next day new sets of flies were used and again transferred to the same monkey, and those flies which had bitten the sick monkey on the previous day (24 hours ago) were placed to bite another unused monkey. In this way new flies were used each day and transferred immediately to the first

FIG 119.—Showing jar method of feeding stomoxys flies on monkeys. The jars are covered with bobbinet and sealed with adhesive plaster The flies thrust their proboscides through the meshes and thus come in contact with the monkey.

healthy monkey; thus this animal always received flies that had fed for the first time on the sick monkey and transferred immediately. The second healthy monkey always received flies supposed to hold infection for 24 hours; the third animal, flies of 48 hours' standing; the fourth animal, flies of 4 days; the fifth animal, flies of 9 days; the sixth animal, flies of 17 days; the seventh, flies of 30 days; and the eighth received daily all the survivors of the entire series until all the flies were dead.

Between monkey feedings until the last animal was used, the flies were kept alive by allowing them to feed on rabbits every other day, a new rabbit being used each time. The rabbits remained healthy.

In the above experiment all the monkeys remained healthy except

two; namely, the first one which received the virus, and that animal died on the fourth day of typical poliomyelitis, and the seventh animal, which died of acute pneumonia.

Except in cases of immediate transfer when only ten minutes of feeding was permitted, the flies were given ample opportunity to feed until satisfied (normally from 20 to 30 minutes) and ordinarily the flies fed well.

In the second experiment an immobilized inoculated monkey was placed in a screened fly cage (16" x 28" x 18") with 500 atomoxya flies. This animal remained in the cage with the flies for two hours, after which it was removed and a healthy monkey substituted (also immobilized). The second animal remained in the cage with the flies also for a period of two hours. This was repeated daily until the inoculated monkey died of poliomyelitis, after which the healthy animal was returned to the cage daily until all the flies were dead. The results proved negative.

In the third experiment the flies in jars as before to the number of about 600 were kept continuously under higher temperatures in the insectary—temperature ranging from 23° to 26° C. The flies were applied for three minutes to the belly and chest of a diseased (poliomyelitis) monkey and then three minutes to the belly, chest and face of a healthy monkey, and thus exchanged back and forth at three-minute intervals until all flies had had a good chance to feed daily. After the death of the diseased monkey the flies were fed daily on the healthy monkey until all the flies were dead. The results were negative.

In the next experiment a fly filtrate, made of flies which had one hour previously fed on a monkey at the height of the disease, was inoculated, intracerebrally, into a healthy monkey with negative results. A filtrate made from flies having fed four days previously also gave negative results.

In the fifth experiment large numbers of flies were applied daily at three-minute intervals between a poliomyelitis monkey and two healthy monkeys and continued daily on the latter after the diseased monkey died. The results were negative as before.

It was thought that possibly the results of the previous investigators had been due to the access of the flies to infectious material on the surfaces of the diseased monkeys and about their body orifices, hence a parallel experiment to the one above cited was undertaken with the difference that the abdomen and chest of the diseased monkey were painted, before the fly feedings, with a mixture of his saliva, his feces, and (late in the disease) his nasal washings in physiological salt solution. Even so the results were negative. Later, after the death of the diseased monkey, an emulsion of the highly infectious brain tissue was used in place of the

mixture of feces, saliva and nasal secretions. The brain emulsion was painted on a normal monkey after which flies were applied and transferred as before to two other normal monkeys, all remaining well. Poliomyelitis had not been produced in a well monkey by stable flies even when they had to drive their proboscides through a layer of highly infectious brain tissue in order to pierce the skin, and the same flies did not transmit the disease on subsequent bitings of two other monkeys.

Conclusions.—From the above-cited experiments the following conclusions were drawn:

1. In a series of seven experiments in which the conditions were varied we were unable to transmit poliomyelitis from monkey to monkey through the agency of the stable fly.
2. Further experiments may reveal conditions under which the stable fly can readily transfer poliomyelitis, but the negative results of our work and of the second set of experiments of Anderson and Frost (loc. cit.) lead us to doubt that the fly is the usual agent in spreading the disease in nature.
3. On the basis of the evidence now at hand we should continue to isolate persons sick with poliomyelitis or convalescent, and we should attempt to limit the formation of human carriers and to detect and control them. Screening of sick rooms against the stable fly and other flying insects is a precaution which should be added to those directed against contact infection, but not substituted for them.
4. The measures used in suppressing the housefly are not wholly applicable to the control of the stable fly owing to its different breeding habits and food supply.

Control of stable fly.—The more important breeding places of the stomoxys can be controlled by removing moist feed wastes from feeding troughs and from feed lots, stalls, stables, etc., and scattering the wastes to hasten drying. Moisture is necessary for the development of the larvae, therefore dry material is not suitable. Weeds, lawn cuttings, decaying onions, vegetation washed up on lake shores, etc., must not be accumulated in piles long enough to ferment and decay.

Bishopp (loc. cit.) has shown that loosely piled straw stacks (oats and wheat) are important breeding places of the stomoxys fly, hence he recommends "that the straw for feeding and bedding purposes be baled and stored under cover. Where this is not practicable the stacks should be rounded up so as to make the top largely rain proof and the sides nearly vertical."

Cattle fly sprays.—Sprays to protect cattle against fly annoyance generally consist of a petroleum oil base, with which is incorporated some toxic ingredient as pyrethrum and rotenone and a repellent such as pine oil. Freeborn, Regan and Berry [20] have devised the following formulae for fly spray, stating that these emulsions equal or excel the better brands of commercial fly sprays. The formulae are:

Formula 1.

Petroleum oil	84 cc.
Unsulfonated residue 90	
Viscosity 97	
Pyrethrum extract (19–1)	48 cc.
Pine oil, steam distilled	48 cc.
Sp. Gr. .... .9377	
B. P. 194–217	
Color .... 1 NPA	
Triethanolamine oleate	16 gms
Water	100 cc.

Dilute one part of this stock emulsion with four and one-third parts of water.

Formula 2.

Petroleum oil (as above)	50 cc
Pine oil (as above)	50 cc.
Pyrethrum extract (as above)	50 cc.
Diglycol oleate	*29.9 cc*

Dilute slowly with eight parts of water, agitating vigorously

The rôle of pine oil in cattle fly sprays has been studied by Pearson,[21] who reports that "pine oil increases (activates) the toxicity of pyrethrum extract, in relation to the amount added. The toxicity of a 1 pound per gallon pyrethrum spray may be maintained by substituting 10, 15, or 25 per cent pine oil for ¼, ½, or ¾ pound pyrethrum, respectively. The effect of pine oil upon the toxicity of rotenone and derris extract is similar.

"Pine oil increases the repellence of pyrethrum extract in relation to the amount added. The repellence of a one pound per gallon pyrethrum spray may be maintained by substituting 10 or 15 per cent pine oil for ¼ or ½ pound pyrethrum, respectively. Pine oil increases the repellence of derris extract in relation to the amount added, but not at as great a rate as that of pyrethrum extract."

C. The Horn Fly

Family Muscidae, Genus Haematobia

Introduction.—*Haematobia serrata* R.-D. [*Lyperosia irritans* (L.)] *is commonly called the horn fly, also known as the Texas fly.* The former name is applied because this fly has the habit of clustering, often in great numbers, at the base of the horns of cattle. Though many believe the fly to injure the horn, there is no foundation for this belief. The position is probably only sought because it affords a safe resting place, especially at night.

As a cattle pest the horn fly has few if any equals; indeed, in the San Joaquin Valley (California) this fly is regarded as the most serious

pest. The horn fly is a comparatively recent introduction into the United States from Europe, where it has been an important cattle pest for many years. According to the U. S. Bureau of Entomology it was first reported in the fall of 1887 from Camden, N. J., appearing during the following year in Maryland and Virginia, probably having appeared in Philadelphia in 1886, and by 1892 was found over the entire continent from Canada to Texas and from Massachusetts to the Rocky Mountains. California cattle men state that it made its appearance in this state in about 1893–1894. It appeared in Honolulu, Hawaii, in 1897.

Characteristics.—The horn fly is about half the size of the common housefly, i.e., about 4 mm. long. It has much the same color and in most other respects resembles the stomoxys fly. The mouth parts (Fig. 120) are as in stomoxys except that the labium is relatively heavier and the palpi, almost as long as the proboscis, are flattened and loosely ensheath the same. The arista is plumose dorsally. The wing venation is as in stomoxys.

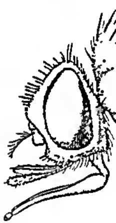

Fig. 120—Side view of head of the horn fly, *Haematobia serrata*

These flies appear early in spring and become most abundant in late summer and autumn. Both cattle and horses are attacked, but most especially the former. When at rest on the animal or elsewhere the wings lie flat on the back and fold rather closely, but when the fly bites, the wings are spread and the insect stands perpendicularly, almost hidden between the hairs of the host. Apparently the habit of resting at the base of the horns is only developed when flies are over-abundant.

Life history.—The horn fly deposits its eggs chiefly, if not exclusively, on freshly passed cow manure. The fly is seen to dart from the animal and deposits its eggs in groups of four to seven, or singly, on the surface of the dung. The eggs are relatively large (1.3 to 1.5 mm.), larger than the eggs of stomoxys; they are reddish brown in color, hence not easily seen on the cow dung. Under laboratory conditions, at least, few eggs are deposited by the females—rarely over twenty. At a temperature of 24° to 26° C., the eggs hatch in 24 hours.

The larvae burrow beneath the surface of the droppings, reaching full growth in from three to five days when they crawl underneath into drier parts and pupate. The pupal period requires from six to eight days. Hence the entire life history (Fig. 121) from the egg to the adult requires from 10 to 14 days at a temperature of from 24° to 26° C.

Damage done.—The damage occasioned by the horn fly is chiefly through irritation and annoyance which results in improper digestion and disturbed feeding, thus producing loss of flesh and reduction of milk

in dairy animals. Dr. James Fletcher estimated the loss in Ontario and Quebec at one-half of the product of meat and milk. Range animals literally run themselves thin in trying to get away from these pests.

The actual loss of blood must be considerable when literally thousands of these flies attack an animal. The weakened condition thus produced lays the animal open to disease. From 10 to 25 minutes are required for the fly to fully engorge itself; during this time the fly withdraws and reinserts its proboscis in the same puncture many times as in a pumping motion. Much undigested blood is discharged from the anus of the fly while in the act of feeding.

Control.—The most effective method to prevent the multiplication of the horn fly is to scatter the droppings from cattle with a rake or other implements or simply by dragging a branch of a tree over the field. Hogs allowed to run with the cattle serve this purpose very well. The manure

Fig. 121.—Life history of the "horn fly," Haematobia serrata. × 4

thus scattered dries out quickly and the larvae if present perish owing to the fact that they require much moisture for development. The writer has seen this method applied most successfully in various parts of California where the dry summer favors this mode of handling the fly. On wide ranges this method is impracticable, but in connection with dairies it is entirely feasible.

Lyperosia exigua (de Meij.) is commonly known as the "buffalo fly" and is particularly important to the cattle and dairy industries of Australia.[22] Among the animals attacked are buffalo, cattle, horse, dog and man. The fly oviposits in fresh dung from buffalo and cattle in particular.

Other species of bloodsucking muscoid flies.—The genus *Philaematomyia* represented by the single species, *P. insignis* Austen, is of particular interest because of the form of the proboscis which is intermediate between the biting and non-biting muscid type. *P. insignis* Austen is a widely distributed African and Oriental species resembling *Musca domes-*

tica Linn. in size and general appearance. According to Austen [23] the proximal portion of the proboscis is a strongly swollen, polished, chitinous bulb, the distal portion being soft and fleshy and folded back under the distal end of the bulb when not in use; when in use its terminal section, consisting of a tubular extension, is protruded from between the labella, and is surrounded at the distal extremity with a circlet of stout chitinous teeth. When not in use the entire proboscis can be retracted within the buccal cavity. Austen states that the fly probably feeds by cutting through the epidermis with the teeth at the end of the tubular extension, and then sucks up the blood.

The Ethiopian genus *Stygeromyia* (*S. maculosa* Austen, and *S. sanguinaria* Austen) is said by Austen (loc. cit.) to be in some respects intermediate between *Stomoxys* and *Lyperosia*. It resembles *Stomoxys* in general appearance and form of the body, but is distinguished "by the relative stoutness of the short, chitinous, horizontal proboscis, and by the palpi being equal to the proboscis in length, large, expanded towards the tips, and curved upwards."

Stomoxys nigra Macquart, *S. omega* Newstead, and *S. inornata* Grünberg, are all Ethiopian species, and resemble *S. calcitrans* in feeding habits.

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CHAPTER XVIII

MYIASIS

Myiasis is a term meaning an invasion by fly maggots of the organs or tissues of animals including man. Such invasions may be benign in effect or may result in more or less violent disturbances, even in death. When the invasion concerns the intestinal tract it is termed *intestinal myiasis*; when the stomach, it may be termed *gastric myiasis*; invasion of the urinary tract, *urinary myiasis*; invasion of the nasal passages, *nasal myiasis*; of the ears *auricular myiasis* or *otomyiasis*; of the eyes *ophthalmomyiasis*; when wounds or ulcers are invaded it is termed *traumatic dermal myiasis*; invasion of the skin is also known as *cutaneous myiasis*, etc.

There are various species of Diptera, belonging to the families Oestridae, Gasterophyllidae, and Cuterebridae which are specifically myiasis-producing, i.e., are obligatory sarcobionts, such as the botflies and warble flies, *Dermatobia hominis* (Linn.), *Gasterophilus intestinalis* (DeGeer) and *Hypoderma bovis* (DeGeer). The more serious myiasis-producing flies are the flesh flies belonging to the family Metopiidae (incl. Calliphoridae, Sarcophagidae, etc.), also the Muscidae. Flies belonging to these families as well as a few others produce accidental myiasis, i e, they are necrobionts or coprobionts, developing primarily in decaying animal matter or vegetable matter as well as in excrement. Those species which are strongly attracted to blood or suppurative material such as the screwworms, *Cochliomyia americana* C. & P., may lay their eggs in wounds and cause dangerous traumatic myiasis. The species which are more typically scavenger in habit (coprobionts and necrobionts) such as *Calliphora vomitoria* (Linn.), *Lucilia sericata* (Meig.) and *Sarcophaga haemorrhoidalis* (Fallén) may lay their eggs or deposit larvae upon the food of man which when ingested may cause intestinal or gastric myiasis.

Identification of fly maggots.—Maggots, the larvae of Diptera, are footless, more or less cylindrical, tapering anteriorly, truncated posteriorly; they are distinctly segmented, with ordinarily 11 or 12 visible segments (Fig. 122). Fully grown larvae differ greatly in length according to the species, ranging from 5 mm. to 35 mm.

At the blunt or posterior end are found the spiracles (Fig. 122) which afford useful diagnostic characters. There are two *stigmal plates* more

or less separated from each other, within which are situated *spiracles* one to three in number, either slit-like, sinuous or more or less circular. A prominence known as a "button" is best seen in certain slit-like forms, as in *Lucilia sericata* (Meig.) (See Fig. 122). The button may be absent or variously situated depending upon the species, hence has taxonomic value.

In using the posterior spiracles as a basis for classification the following characters are to be noted, viz., (1) *diameter* of the stigmal plate,

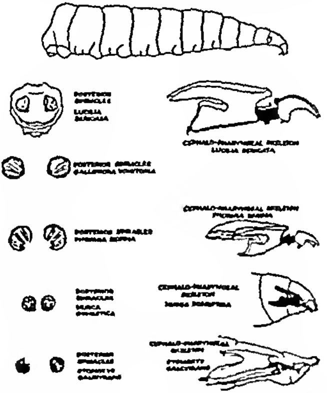

FIG. 122.—Showing taxonomic details used in the classifications of muscoid fly larvae (Redrawn after various authors.)

the space occupied by one stigmal plate on a line drawn through the center of both; (2) *length*, when slits are absent, the space occupied by a plate on a line drawn dorsoventrally through the center of the plate; or, when slits are present, the space occupied by a plate along a line drawn from the lower edge of the button (or space if button is absent) through the longest slit (middle slit) to the margin of the plate; (3) *width*, along a line drawn at the middle of the plate at right angles to the *length* line; (4) distance between the plates; (5) general form of the plates; (6) shape of spiracles; (7) presence or absence of *button;* (8) general structure of plate.

Intestinal myiasis.—According to Braun and Seifert [1] at least thirty species of fly larvae have been reported from cases of intestinal myiasis. They are principally members of the families Muscidae and Metopiidae which commonly deposit their eggs or larvae on cold meat, cheese, and other foods of man and are thus ingested. It is also suggested that the flies may deposit their eggs in or near the anus, particularly in the use of old-fashioned open privies. The larvae on hatching are believed to make their way into the intestine. Hoeppli and Watt (1933),[2] experimenting with the larvae of *Chrysomyia megacephala* (Fabr.) and *Lucilia sericata* (Meig.), secured results that agree with those obtained by Desoil and Delhaye (1922)[3] with larvae of *Calliphora vomitoria* (Linn.) showing that fly larvae of certain kinds as well as the eggs are able to resist the influence of temperature, gastric juice, hydrochloric acid and ferments in all the concentrations occurring in the human stomach, but that the larvae are very susceptible to mechanical injuries and to the obstruction of their stigmata. Ample food for the larvae is provided by the intestinal contents as well as the intestinal mucosa itself.

The clinical symptoms of intestinal myiasis depend on the number as well as the species of fly larvae and on their location in the intestine. No doubt many instances occur in which living fly larvae are passed in the stool without causing symptoms. Usually there are nausea, vertigo and more or less violent pains in the abdomen; diarrhea with discharge of blood may occur as the result of injury of the intestinal mucosa by the larvae Living and dead larvae are expelled with either the vomit or stool, or with both.

An obstinate case of intestinal myiasis is reported by Herms and Gilbert (1933).[4] The patient, Z. W., female, age 38 years, was first seen April 26, 1930. Her chief complaints were attacks of nausea, vomiting and diarrhea, nervousness and joint aches. There were recurring attacks of nervousness, vomiting and diarrhea and apparently rather frequent hemorrhages from the bowels. The patient was considerably depressed at times and treatment was difficult because of lack of coöperation except after she had had a bad spell. Because of the difficulty of obtaining stool specimens, especially during the acute attacks, and in view of the fact that it was felt that there must be other reasons for her condition, early in the spring of 1931 during an attack of nausea with vomiting and diarrhea the patient was kept for one entire day in the office under observation and stool and vomit specimens were obtained, both containing the first larvae which were studied. During these attacks it was difficult for her to obtain relief with fairly large doses of opiates. Following this observation she was given santonin by mouth and colonic irrigations containing thymol. Many larvae were recovered after this, all of which

were dead. Following the attacks of diarrhea the patient had a number of severe hemorrhages. Tetrachlorethylene capsules were given by mouth but they caused gastric distress. In the hospital a duodenal tube was passed and tetrachlorethylene was injected beyond the stomach. For a few weeks there was apparent improvement, but the attacks recurred, with the passage of larvae by vomiting and bowel discharge.

Three lots of fly larvae were studied in the laboratory, i e., March 31, 1931, May 12, 1931, and July 28, 1931. Adult flies belonging to three genera, *Calliphora, Lucilia* and *Sarcophaga,* were reared from these larvae.

The recurrence of violent symptoms with extrusion of larvae in vomit and stools would ordinarily point to repeated infections, but the fact remains that the patient lived in a way that would seem to preclude repeated infestations and the exposure of stools and vomit to flies is ruled out because of the circumstances indicated in the case report. The authors have advanced a possible explanation based on the pedogenetic reproduction of fly larvae as suggested by observations made by Parker (1922),[5] viz.: "The increases led me to believe that *Calliphora erythrocephala* occasionally multiplies in an unusual way, and that this way is not polyembryony but pedogenesis." In the case described there were certainly broods of very young larvae at intervals, at which time also full grown larvae were present.

Cheese skippers.—The larvae of the cheese fly, *Piophila casei* (Linn.) of the family Piophilidae, frequently cause intestinal myiasis, as they are able to pass through the digestive tract without injury. Simmons[6] cites a number of instances indicating the frequency of their occurrence in the digestive tract of man. The adult flies measure from 2.5 to 4 mm. in length; superficially they appear shining black, with reddish brown eyes and wings held flat over the dorsum when at rest. The eggs are deposited on cured meats, old cheese, dried bones, smoked fish and many similar materials. The eggs hatch in from 30 to 48 hours at a temperature of 65° F.; the larval stage requires about eight days, the pupal about twelve days These stages are greatly influenced by temperatures. The larvae have the peculiar habit of curving the ends of the body together and then suddenly springing to a distance of from three to six inches.

Soldier fly.—A case of intestinal myiasis caused by larvae of a soldier fly, *Hermetia illucens* (Linn) (Family Stratiomyidae), is reported by Meleney and Harwood.[7] This fly feeds mainly on flowers, and the eggs are deposited on decaying fruits, vegetables, and animal matter. The source of infection according to the authors was apparently raw fruit or vegetables. The symptoms were local irritation in the stomach and rectum, and spells of fainting. The patient was a boy of ten years M. A.

deposits its eggs on liquid manure or other filthy liquids in cans, slop jars, privies, septic tank effluent, etc. The larvae are known as "rat-tailed larvae" (Fig. 124); these also occur occasionally in heaps of horse manure.

The family Syrphidae includes a very large group of flies, varying greatly in size, many of which are brightly colored. They are nearly all flower loving, feeding on nectar mainly. Only one genus needs to be considered here, namely *Eristalis*, the larvae of which have a long anal breathing tube, i.e., "rat-tailed," and the adults of which are commonly called drone flies.

Urinary myiasis.—As in intestinal myiasis the symptoms of urinary myiasis depend on the number and kind of larvae and their localization. There may be obstruction, pain, pus, mucus and blood in the urine and a frequent desire to urinate. Larvae are expelled with the urine. Chevril [10] reports that *Fannia canicularis* (Linn.) (see Chapter XV) is most frequently found in urinary myiasis, although *Fannia scalaris* (Fab.) and *Musca domestica* Linn.[11] have been encountered. Hoeppli and Watt (loc. cit.) believe that albumin and sugar in the urine may provide food as may mucus and leucocytes; the lack of oxygen presents the chief difficulty, although very small amounts of oxygen are needed by the larvae.

Infection is probably usually accomplished during sleep in warm weather when persons may sleep without covering, the flies depositing their eggs around the urethral opening and these hatching in a few hours, the larvae enter the urethra.

Traumatic dermal myiasis, the invasion of wounds or ulcers of the skin by fly larvae, is of common occurrence in warm, humid climates. A large number of species of flesh flies are responsible for this type of myiasis, particularly the screwworm flies, green-bottle flies and related species.

The following description of a case caused by *Phormia* [illegible] *gina* (Meig.) reported by Stewart [12] will serve to illustrate this form of myiasis.

"The dermatitic area was not large at first but it continued to spread after hospitalization. An extremely offensive odor was given off, but aside from the [illegible] of the sores the patient appeared to he feeling well; [illegible] first treatment was applied only [illegible] of the patient's admission to the [illegible] was a mass of pus and a supersaturated sulphur wash was applied. The hair was parted to allow the wash to penetrate freely to the scalp and a towel was tied about the head, coming below the ears. The supersaturated sulphur wash was applied every two hours.

"After the second treatment was applied to the scalp the patient became very restless, working the fingers into the palms of her hands and alternately

putting her hands to her ears. Soon she began to scream, acted frantic, and became nearly delirious. She was given a sedative without effect.

"On taking the towel from the patient's head the nurse observed fly larvae, which had been forced into activity by the treatment, crawling over the towel, hair and down the cheeks. The nurse estimates that she killed twenty-five or thirty larvae in the hour and a half she spent in removing them and still the hair and scalp remained full of them. Back of the ears the mass of living larvae was so great that they could almost have been spooned out. At this time the patient complained of a buzzing in the ears similar to that occurring when the ears are full of water, and said that she could not hear. The nurse then used toothpick swabs to remove the great quantity of larvae found in the pinnae of the ears; in so doing most of the larvae were killed, but some were kept alive and placed on raw beef in vials so that they might complete their larval growth and pupate.

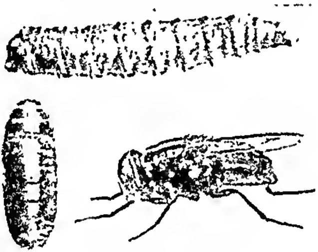

FIG. 125.—*Cochliomyia americana*, the Texas screwworm fly, larva and pupa. (After Bishopp.)

"As soon as pupation occurred the puparia were removed to fresh vials and covered with fine dry soil until they emerged as adults, when they were identified as *Phormia regina* Meig.

"After the removal of all visible larvae had been completed the patient's hair was clipped, the supersaturated sulphur wash treatment was continued, and the scalp was bandaged. To the original area of dermatitis around the ears was applied a paste consisting of salicylic acid, 2 gm.; zinc oxide, 24 gm.; starch, 24 gm.; petrolatum, sufficient to make 100 gm.

"It is obvious that an adult female fly had been attracted to the suppurating scalp sores by the foul odor given off and had oviposited in one or more of these sores. The larvae were driven from the scalp to the pinnae of the ears by the application of the supersaturated sulphur wash."

Stewart [11] in another article describes a new treatment for traumatic dermal myiasis:

"A new douche, composed of 15 per cent chloroform in light vegetable oil, has been employed in the treatment of seventeen cases of traumatic dermal myiasis. In every case all the maggots were removed with a single treatment, extending over a period of thirty minutes.

"The new douche has advantages over the commonly used chloroform
solution in that
soluble in milk;
can be kept indefinitely in closed containers at
ture has to
is very soot

FIG. 126.—*Cochliomyia macellaria* just emerged from the pupa cases. A dead animal near by furnished food for the larvae, pupation took place in the sand underneath the carcass. The newly emerged flies have crawled up on the grass and will soon be ready to fly away. Note characteristic resting attitude, with head down.

Cochliomyia americana C. & P. (Fig. 125) is the name recently given to the New World screwworm fly by Cushing and Patton [14] to separate this dangerous form which feeds on the tissues of living animals from *Cochliomyia macellaria* (Fabr.) (Fig. 126) which is more particularly a scavenger fly. It is an obligate parasite and according to Laake, Cushing and Parish initiates the great majority of cases of screwworm infestations in man and animals in the United States and probably in the entire Neotropical region. It is known to be the common cause of nasopharyngeal myiasis in man.

Osborn (1896) quotes Richardson in the Peoria, Ill., Medical Monthly for February, 1883, who describes a typical case thus:

"While traveling in Kansas in the latter part of last August, a citizen of this place had the misfortune to receive while asleep a deposit of eggs from this fly. He had been troubled for years with catarrh, hence the attraction to the [illegible] ...nt and shortly after began [illegible] was called to attend him. [illegible] a man laboring under a [illegible] moderate fever. His nose seemed greatly swollen and he complained of a smarting, uneasy feeling in it, and general misery through the head. Gave him treatment to relieve the congestion and fever Tuesday, saw him again. His nose and face were still swollen, and in addition to the other symptoms he was becoming slightly delirious and complained a great deal of the intense misery and annoyance in his nose and [illegible] nostril. Making a 20 per cent solution of chloroform in sweet milk I made a few injections up both nostrils, which immediately brought away a large number, so that in a few hours I had taken away some 125 of them. By Wednesday evening erysipelas had begun, implicating the nose and neighboring portions [illegible] their way into so many recesses of the nose and were so firmly attached that we were unable to accomplish much. Finally we resorted to the chloroform injections, which immediately brought away a considerable number. Friday I was able to open up two or three canals that they had cut, extracting several more that had literally packed themselves, one after another, in these fistulous channels His speech becoming suddenly much worse, I examined the interior of his mouth and found that a clear-cut opening had been made entirely through the soft palate into his mouth and large enough to insert the end of a common lead pencil. Saturday the few remaining larvae began changing color and one by one dropped away. On Sunday for the first time hemorrhage from both nostrils took place, which continued at intervals for three days, but was not at any time severe. On this day the patient began to improve, the delirium and [illegible] after an illness of nearly three weeks, completely exhausted by his prolonged sufferings. Three days before his death the abscess discharged its contents by the left nostril. The quantity of pus formed was about 2½ ounces (78 grams).

"In all about 250 larvae were taken away from him during the first attack, and, as the visible results, not only had they cut the hole through the soft palate, but had also eaten the cartilage of the septum of the nose so nearly through as to give him the appearance of having a broken nose. The case occupied, from the first invasion of the fly to its final result, nearly two months. He doubtless would have recovered but for the formation of the abscess, which from all the symptoms, was caused by one or more of the larvae having found their way up the left eustachian tube."

Cochliomyia americana C. & P. is strongly attracted to the wounds and sores of animals. Laake [15] estimates the loss occasioned by this fly in the Southwest of the United States at $5,000,000. Laake found the following predisposing causes of attack: among sheep and lambs, wounds caused by needle grass take first rank; among goats and kids, shear cuts take first rank; among cattle, injuries by the horns of other cattle; among calves, exposed tissue at birth; and among horses and mules, wire cuts.

Laake points out that the more common causes of screwworm attack are due *to farm practices that can be corrected. He stresses particularly* care in shearing, dehorning, removing and disposing of old barbed wire from dismantled fences, also the timing of dehorning, castrating and branding so as to expose the wounds as little as possible to flies during the season of abundance.

Life history of the screwworm fly. The adult fly of *Cochliomyia americana* C. & P. has a deep greenish blue metallic color with yellow, orange or reddish face, and three dark stripes on the dorsal surface of the thorax. It is difficult, unless one is experienced, to separate this species from *Cochliomyia macellaria* (Fabr.). Laake, Cushing and Parish state that the females of *C. macellaria* (Fabr.) may usually be distinguished from *C. americana* C. & P. by the fact that the basicostal scale (a small sclerite at the base of the wing) of the former is of a yellowish color, whereas in the latter (*C. americana* C. & P.) it is black. Also *C. macellaria* (Fabr.) is covered on the midline of the underside of the abdomen by a dense white pruinosity absent in *C. americana* C. & P. The species can be easily and accurately determined by the use of the characters exhibited by the male terminalia.[16]

Individual females of *Cochliomyia americana* C. & P. according to Laake, Cushing and Parish, may lay as many as 2,853 eggs, the eggs being deposited in characteristic batches of 10 to 393 eggs each, and the laying of as many as 300 eggs may be completed in from four to six minutes. The incubation period of the eggs on wounds in animals ranges from 11 to 21.5 hours, under natural conditions. The larval feeding period ranges from 3.5 to 4.5 days; the prepupal from a few hours to about three days (7 hours to 76 hours); the pupal stage about seven days. The prepupal and pupal stages are greatly influenced by temperature and moisture. The life history from egg to adult under optimum natural conditions requires about 11 days.

The larvae of *Wohlfahrtia vigil* (Walk.) were taken by Walker [17] in three cases of cutaneous myiasis. The case of a five-month-old boy is described thus:

> "Most of the lesions were clustered together on the left side of the neck under the angle of the jaw, one being on the left cheek. They had been first noticed by the mother 24 hours earlier, and when seen by the writer they were

already secondarily infected with pus organisms, the child being in a poor general condition and suffering from an intestinal disorder. They were similar to the lesions observed in the previous cases, each being a boil-like sore with an external opening, and from these openings five or six larvae had already been expressed. Only three additional larvae were obtained, these measuring 5 to 7 mm in length Each was placed on raw beef in a separate test-tube, plugged with cotton wool. In 24 hours they reached a length of 12 to 13 mm., and in another 24 hours they were full-grown, each measuring about 17 mm. in length.

"On the third day after their removal from the child the larvae were placed with the meat in a jar of earth and immediately burrowed into the latter. Next day they were at the bottom of the jar and two of them had begun to contract Three days later they were dug up and all had transformed into puparia.

"On September 27, 18 days later, a male *Wohlfahrtia vigil* emerged. I waited for the others to appear until October 5, but neither having emerged by that time I opened one of the puparia on that day and the other a week later, and in both I found pupae which had evidently died some time before the proper time for emergence, as they were quite colorless In this case, like the previous ones, the child recovered rapidly after the removal of the maggots."

Creosote oil.—It has been found that surfaces treated with creosote oil are repellent to flies for many days and that dead bodies completely covered with it so as to prevent maggots from gaining a foothold do not become invaded. From one-half to a gallon of the oil is said to be sufficient for the carcass of a horse The skin quickly hardens and becomes leathery, the body remaining well preserved for weeks.

Sodium cyanide.—Under oriental conditions innumerable flies (said to be *Chrysomyia spp*) originate in the receptacles (*feng gang*) used to store human excrement. This dangerous condition is undoubtedly responsible for much of the dysentery that exists during the fly season. Professor C. W. Woodworth, who has spent considerable time in China, has informed the author that a remarkable reduction in the fly population of Nanking was brought about by the application of a solution of sodium cyanide (one ounce to a gallon of water) to the contents of the vessels. The cyanide solution was applied by means of a sprinkling can.

Dermal creeping myiasis of man is commonly caused by the wandering larvae of flies belonging to the family Cuterebridae, particularly *Dermatobia hominis* (Linn); and also *Hypoderma lineata* (de Villers) and *Hypoderma bovis* (DeG), both known as ox warble flies, belonging to the family Oestridae.

Dermatobia hominis (Linn) is commonly found in Central and South America and Mexico. "The larva is known in its early stage as *Ver macaque* and in its later stages as *torcel* or *berne*. The fly measures from 14 to 16 mm in length and is entirely brown in color. This fly parasitizes a large number of species of mammals and even birds It has been found in cattle, pigs, dogs, mules, monkeys, man and various wild animals. In man the larva has been reported from various regions of the body,

mainly head, arm, back, abdomen, scrotum, buttocks, thigh and axilla" (Ward).[18]

Although it is not certain that this *Dermatobia* does not deposit its eggs directly on or in the human skin, it is now known that several species of mosquitoes and ticks, particularly the mosquito *Psorophora (Janthinosoma) lutzii* (Theo.) and possibly other insects act as intermediate carriers of the eggs. The female *Dermatobia* is said to oviposit on the undersides of the bodies of the mosquitoes so that when the latter suck blood, it is possible for the eggs to come in contact with the warm-blooded host where either contact or warmth stimulates the larvae, rapid emergence results and entrance to the skin of the host is effected. The larval period in the body of the host is said to require about two and a half months when, like the *Hypoderma* species, the larvae leave the tumorous swellings they have produced, drop to the earth and pass through a pupal period requiring from three to six weeks.

Dunn[19] (1930) has described the life history of the human botfly most accurately as the result of an infestation which he suffered in the Panama Canal Zone. In his case the fly *Limnophora*, not a bloodsucker, was the vehicle for the eggs. Two larvae were observed to enter the skin of his arm, requiring 42 minutes for the first and one hour and 35 minutes for the second. Dunn experienced "absolutely no sensation caused by the entrance of the (first) larva until after the first 30 minutes. Then, as the posterior end was being drawn inside, a sharp pricking, which lasted for about two minutes, was experienced." He states that there was at first a sharp itching at night, and by the end of a week the lesions were exuding serous fluid at times. By the end of two weeks the lesions had the appearance of small boils and by the end of three weeks these were excruciatingly painful. At the end of 46 days and 15 hours and 50 days and 15½ hours respectively the larvae emerged from the skin, causing "absolutely no pain or sensation." The pupal periods were from twenty-two to twenty-four days.

The above account of an infestation of human bots supports the opinion of other authors that the larvae remain in a relatively fixed spot in the subcutaneous tissues. The larvae of the ox botfly on the other hand have the tendency to migrate in the subcutaneous tissues often for considerable distances.

The author[20] (1925) has described the migrations of the larvae of *Hypoderma bovis* (DeG.) thus:

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Whether this exposure was taken advantage of by the fly can only be a matter of conjecture. Several days later, exact time not remembered, soreness was experienced and a slight swelling in the region of the right groin appeared. In about a [illegible] following about the same course to the left groin, thence across to the right groin and back again to the left and upward along the left side of the body, slightly anterior to the shoulder, thence downward to the upper right arm to near the elbow, when the arm could not be raised without great pain, thence the swelling travelled upward again to the neighborhood of the shoulder blade where a 'hive-like' local swelling was formed without any itching sensation. Mr. C. stated that at this point he was 'bothered' all night, and while rubbing his arm and manipulating his shoulder muscles a larva of some insect 'popped' out. This emergence took place about the end of October (1924). The larva was placed in a vial for shipment but was lost in transit.

"Relative to the second larva which was delivered to the writer in person on the day following its emergence, Mr. C. states that since October when the first larva emerged, no further swellings were observed, but soreness in the region of the thigh and lower abdomen, similar to severe strain, persisted. However, on January 28 (1925) he experienced a severe 'soreness' in the region of his right thigh which gave much distress, particularly when walking. By that night a swelling had developed and the following day the muscular soreness continued to spread, by January 31 a hernia-like swelling had developed which enlarged upward and outward to the region of the belt-line, the lower hernia-like swelling gradually disappearing. Sunday night, February 1, a hive-like swelling as observed in the case of the first larva began to form, enlarging to an area of about four by eight inches Tuesday evening, February 3, lymph exuded from a small opening near the middle of the swollen area About a tablespoonful of lymph stained with blood was pressed out and in the process of manipulation a larva similar to the first 'popped' out This specimen was delivered to the writer February 4 in good condition and identified as a third-stage larva of *Hypoderma bovis* DeG. The larva was milky white in color, about 12 mm in length by 2 mm. in width at the middle, tapering bluntly at both ends. Very little swelling and practically no discoloration were visible on examination, although the point of emergence was clearly seen"

Ophthalmomyiasis of man is more particularly traceable to the larvae of head-maggot flies of sheep, deer and related animals Cases traceable to *Oestrus ovis* Linn. [*Cephalomyia ovis* (Linn.)] of sheep and *Rhinoestrus purpureus* (Brauer) are frequently reported in European horses. Three first-stage larvae of *Oestrus ovis* Linn. measuring about 1 mm in length that had been removed from the eye of a patient in Honolulu by Dr. R. Faus were studied by the author [21] (Fig 127). The attending physician reported that the three larvae were buried in the sclera and were extremely adherent to the conjunctiva, causing acute conjunctivitis, lachrymation, ulceration and neurosis.

These flies belong to the dipterous family Oestridae and are world-wide in distribution. *Oestrus ovis* Linn. is something over half the size

of a honeybee; the thorax is yellowish in color, though the color in general is grayish. The female fly deposits living young during the heat of the day, usually by striking the nostrils of the appropriate host. One female fly has been observed to deposit 60 larvae in an hour. The larvae travel up the nasal passages, eventually occupying the nasal and frontal sinuses. It is quite probable that sheep and other hosts, as well as man, may receive the larvae in the eye where the route to the nasal sinuses via the lachrymal duct might at least be open, though it is perhaps seldom taken.

Wool maggots.—Blowflies, inclusive of the screwworm fly already discussed, were undoubtedly at one time solely scavengers feeding in the maggot stage on carrion and animal wastes, but with the introduction of herds of domesticated animals they acquired the habit of attacking living animals. The term "blowfly strike" is applied to the condition, cutaneous myiasis, produced by the development of blowfly maggots on living sheep. Froggatt[22] writes:

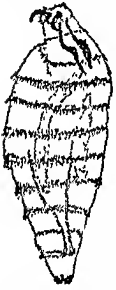

FIG. 127.—Larva of *Oestrus ovis* from eye of human.

"It is frequently stated, and with a certain amount of truth, that the 'blow-fly pest' was known in New South Wales forty years ago, but it was only in isolated cases and under exceptional conditions that live wool was then blown.

days, but the almost universal infestation of otherwise healthy sheep, simply because the wool of the crutch, rump or flanks becomes wet and stained has only become a real menace to sheepowners within the last twenty-five years" (Written by Froggatt in 1922.)

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simply scavengers or flesh-flies that deposited their eggs in animal matter that happened to be festering in the sun. In the study of economic
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of blowing live wool from the practice (already acquired) of blowing the wool of sheep that had died from some other cause. The smell of the dead wool taught them that the damp or soiled wool on a live sheep was of a similar character, and once the maggots set up decomposition of the yolk and fibre the smell attracted other flies. Thus other species became sheep-maggot flies until all our common blowflies had learned the habit.

"To upset the balance of nature is always a dangerous undertaking, and there is not much doubt that it has been the destruction of the natural means of control of the fly and the provision of a much larger number of suitable breeding-grounds that has caused the remarkable increase in the number of flies. After great droughts landowners have had to fight millions of rabbits

breeding all over the West, and poisoned water and poison-carts have been put to considerable use. Sometimes the dead rabbits were stacked up and left to rot; sometimes they filled up the water-holes; sometimes they were piled up feet high along the wire-netting fences It can be easily understood that under such conditions the blow-flies must have increased a millionfold. Again, [illegible] birds that capture the flies, but often only after they have deposited their eggs on the sheep.

"The next, and perhaps the most important, factor in the development of the sheep-maggot pest is the work of sheep-breeders themselves. Forty years ago there were many thousands of Merino sheep of the bare-belly, bare-legged type, which did not produce a third of the weight of wool of the modern, improved Merino The ambition of every sheep-breeder has been to make every inch of the sheep's skin grow wool, and in the case of some classes of Merinos to produce a wrinkled skin, giving even more wool-bearing surface A sheep clothed with such a mass of thick, close, fine wool, fitting closely over the rump and round the tail, is sure to get more or less stained and damp round the crutch, and to attract flies. This artificial increase in weight, quantity and fineness of wool is accompanied, too, by an increased secretion of yolk, which rising from the skin and spreading all through the wool fibre, forms an additional attraction for the flies, and supplies food for the maggots"

The following species of flesh flies are listed by Froggatt and other authors as attacking live wool· *Phormia regina* (Meig) known as the black blowfly because of its blackish-blue color and regarded as the most important wool-maggot fly of Texas and California; *Lucilia sericata* (Meig), resembling *Lucilia caesar* (Linn) very closely but being brighter because of the stronger coppery color, an important sheep maggot fly in Australia and other parts of the world; *Chrysomyia albiceps* (Wied.) [*Chrysomyia* (=*Pycnosoma*) *rufifacies* (Macq)], common in Australia and India; *Cochliomyia americana* C. & P, a menace to sheep raising, particularly in the Southern States of the United States, Mexico and elsewhere in the range of this insect, *Chrysomyia bezziana* (Villen) [*Chrysomyia flaviceps* (Wlk)=*Chrysomyia dux* (Esch)], an important Australian and Oriental sheep maggot fly; *Wohlfahrtia magnifica* (Schin), the principal sheep maggot fly of southern Russia, also causes human myiasis in Egypt.

Control of wool-maggot flies.—The following measures for the prevention and treatment of "blowfly strike" are recommended by various workers among them Babcock and Bennett [33] of the Texas Agricultural Experiment Station and Belschner [34] of the New South Wales Department of Agriculture· (1) *Carcass burning*—dig a trench along the back of the carcass nearly as wide as the animal and as long, and twelve to fourteen inches deep; fill trench with wood (one-quarter cord of wood sufficient to burn cow or horse) or cow chips; start fire at windward end

and entire carcass will be entirely consumed within twelve to twenty-four hours. (2) *Poisoning*—a freshly killed animal is very attractive to flies, and if treated with an arsenic solution will kill every fly that feeds on it, or if a carcass is already alive with maggots, a similar treatment will kill these also. For this purpose arsenite of soda at the rate of three pounds to thirty gallons of water is recommended. (3) *Screening*—by placing four upright stakes at each corner of a fly-blown carcass and covering well with sacking to catch the emerging flies which are left to die for want of food and moisture. (4) *Trapping*—large fly traps properly placed and baited with a small dead animal (cut open) or with entrails will assist in reducing the flies. (5) *Crutching*—if properly done prevents the attack of flies by reducing the opportunity for the wool of the crutch, rump and flanks to become wet and soiled and thus attractive to flies. It consists particularly of shearing the wool away from the breech, over the tail and down the back of the hind legs. (6) *Jetting*—applying an arsenic solution (one pound of arsenic to forty gallons of water) by means of a single jet under pressure of 125 pounds to the rump of the sheep: in this way the arsenic is forced through the wool to the skin, where it dries and protects the animal for a longer time than spraying. (7) *Parasites*—the use of parasites against the flies is advocated and *Nosonia brevicornis* Gir. & Sand., a common chalcid wasp, has been bred in great numbers in New South Wales and is being successfully used as a parasite of the fly pupae.

Foot maggots of animals.—A lameness that varies in degree and is traceable to myiasis commonly occurs in Philippine cattle, carabaos and goats and is caused by the larva of *Boöponus intonsus* Ald. Woodworth and Ashcraft [25] state that the eggs of this fly are attached to the hairs of the lower portions of the legs of the host animal, the incubation period varying from three to five days. The young larvae work their way down to the coronary and neighboring parts and enter the flesh, leaving their posterior ends exposed, and when full grown at the end of two to three weeks they leave the flesh and drop to the ground where they bury themselves and pupate, the pupal period requiring about ten days.

The method of treatment suggested by these authors consists of cleaning the affected area with soap and water, removing as many maggots as possible and applying a chloroform pack, followed by heavy applications of *pix liquidae* every third day until the lesions heal. As a preventive means, daily inspection is recommended of all cattle, carabaos and goats, especially during the dry season when the animals should have access to plenty of water and mud as wallows.

Toxic effect of ingested fly larvae.—A disease known as "limberneck" in chickens is believed to be traceable to the ingestion of large numbers of fly larvae [*Lucilia caesar* (Linn.), *Lucilia sericata* (Meig.) and no doubt other species of flesh flies] or meat infested with type C

Clostridium (=*Bacillus*) *botulinum* (Van Ermengem).[26] It is believed that the organism multiplies in the unburied bodies of dead animals, as flesh is a favorable medium for growth, and that the flesh flies developing in the carcasses become infected and in turn chickens eating the maggots (or the flesh) acquire the infection. This is another good reason why dead animals should be speedily and safely disposed of, preferably by incineration.

Tumbu fly and Congo floor maggot.—Several tropical African species of calliphorine flies (Metopiidae) are commonly referred to in the literature on myiasis, among them *Cordylobia anthropophaga* (E. Blanchard), the "tumbu fly." Austen describes it as being a "thickset, compactly built fly, of an average length of about 9½ mm. . . . Head, body and legs are straw yellow." According to Blacklock and Thompson [27] the eggs are deposited in excrement-polluted sand and soil. The incubation period may be as short as 24 hours. If contact is made with the skin of man or other animals, the larvae penetrate the unbroken skin, forming furuncular swellings or where multiple and contiguous infection occurs, extensive "sloughing and gangrenous" conditions result In eight to ten days the full-grown larvae, measuring 13 to 15 mm. in length, leave the host and pupate in a few days. Wild rats are looked upon as the main reservoir of the infection in nature

In the same locality with the "tumbu fly" there may occur *Auchmeromyia luteola* (Fabr.), the larva of which is a bloodsucker and is known as the "Congo floor maggot." The fly is commonly found about human habitations. The eggs are deposited in small clusters in various situations, such as on sleeping mats spread on the ground in huts, in dusty crevices, in dry sand, situations where the larvae may readily find suitable food. According to Roubaud,[28] whose treatise on this insect should be read by all concerned, the eggs hatch in 36 to 40 hours. The larvae are remarkably resistant to extreme dryness and lack of food. They are nocturnal in their feeding habits, sucking the blood of sleeping persons, producing a wound by means of powerful buccal hooklets They feed for 15 to 20 minutes, detach and hide in the crevices of mats, etc., during the day, repeating the attack almost nightly if hosts are available. The larval period may be as short as two weeks or, in the absence of food, perhaps as long as three months when the larvae pupate in protected situations. The pupal stage lasts from 11 to 12 days.

Bloodsucking maggots of birds.—In a study of bloodsucking fly larvae in birds' nests Plath [29] found an average of 61 per cent of a total of 63 nests examined to be infested with an average of 47 maggots per nest. The species of birds were the Nuttall sparrow, California purple finch, greenback goldfinch, willow goldfinch and California brown towhee. In a later paper the same author [30] adds several other species,

namely the rusty song sparrow, cliff swallow, Oregon towhee, yellow warbler, western robin, russet-backed thrush and cedar waxwing. The species of flies responsible for the maggots were found to be *Protocalliphora azurea* (Fallén), *Phormia metallica* Town., both flesh flies, and *Hylemyia nidicola Ald.*, an anthomyid fly (family Muscidae). Storer[31] reports taking 76 larvae and 24 pupae from the nest of the Bailey mountain chickadee. These were identified by Aldrich as *Protocalliphora splendida* variety near *hirudo* S. & B.

Plath concludes that from 5 to 10 per cent of the parasitized nestlings die from loss of blood, and some of them which do become full fledged are so weakened by the loss of blood that they fall an easy prey to rapacious animals.

Botflies and Warble Flies

Obligatory myiasis.—The larvae of oestrid flies are the specific cause of obligatory myiasis. Heretofore the family Oestridae comprehended all the species of horse botflies and warble flies, but Curran (loc. cit.) has separated them into three families, the Gasterophilidae, Oestridae and Cuterebridae.

Fig. 128.—Eggs of the horse botfly, attached to a hair of the host. × 20.

The horse **botflies** belong to the family Gasterophilidae with only one genus *Gasterophilus*[32] and four North American species, (1) *Gasterophilus intestinalis* (DeGeer) with cloudy patches near the center and apex of the wings and possessing a prominent spur on the third trochanter; (2) *G. inermis* (Brauer), wings also with cloudy patches, but the trochanter is without a spur; (3) *G. haemorrhoidalis* (Linn.) without cloudy patches on the wings in which the anterior basal cell is markedly shorter than the discoidal cell and the tip of the abdomen is reddish; and (4) *G. nasalis* (Linn.) also with hyaline wings and anterior basal cell equal or nearly equal in length to the discoidal cell. The flies of this genus are somewhat smaller than honeybees, the mouth parts are rudimentary, the antennae are very small and sunken in pits, the arista is bare, and according to Curran the apical cross-vein is absent, the vein closing the discal cell is also absent and the fourth and fifth veins evanescent apically, squamae small; the ovipositor of the female is large and protuberant. They are strong fliers. The larvae live in the stomach and intestines of horses.

Gasterophilus intestinalis (DeGeer) [*Gasterophilus equi* (Clark)] is the common horse botfly or nit fly, a widely distributed, nearly cosmopolitan, species commonly seen in the United States during midsummer to

early autumn, June to September. The light yellow eggs (Fig. 128) are firmly attached to the hairs of the forelegs, belly, flanks, shoulders, and other parts of the body of the horse, but chiefly on the inside of the knees where they are accessible to the tongue, teeth and lips. The female fly (Fig. 129a) hovers from two to three feet away from the animal, darting swiftly and repeatedly at the horse, each time attaching an egg to a hair. Wells and Knipling (loc. cit.) report one fly placing 905 eggs in 2¾ hours. Friction and moisture from the tongue of the horse seem necessary for the hatching of the eggs, the incubation period is from 7 to 14 days, but may be greatly prolonged by cool weather so that viable eggs may be found unhatched on the hair of the horse until late autumn, long after the flies have disappeared. Eggs kept in dry cartons may remain viable at room temperature for at least three months and hatch when moistened with saliva. The larvae on hatching (Fig. 130) are provided with an

Fig. 129.—Horse botflies, (a) *Gasterophilus intestinalis*, (b) *G. haemorrhoidalis*, (c) *G. nasalis*. (Adapted after Hearle.)

armature which enables them to excavate galleries in the subepithelial layer of the mucous membrane. Wehr,[33] who has studied the behavior of the larvae, states, "Many very small, thread-like subepithelial burrows, ramifying in every direction, were visible on the anterior half of the tongue, while those on the posterior half of the tongue were larger in size. Larvae were visible at the terminations of many of these galleries." Wehr found that newly hatched larvae when placed on the tongue of a freshly killed rabbit almost immediately began burrowing and within one minute nearly all became entirely embedded in the mucous membrane. From the mouth in the normal host the larvae apparently pass rapidly to their preferred site in the alimentary canal, the left sac or oesophageal portion of the stomach, where third (even second) instar and the final instar larvae remain fixed with little or no change in position until the following spring and early summer when they detach themselves and pass out of the intestine with the droppings. They are then from 1.5 to

2 cm. in length (Fig. 131). Pupation takes place shortly thereafter in loose earth or in dry droppings. The pupal stage varies considerably, depending upon moisture and temperature, but the usual time is from three to five weeks when the winged botfly emerges. Copulation soon takes place and egg laying begins in early summer. The life history requires about one year.

Gasterophilus haemorrhoidalis (Linn.) (Fig. 129b) is a North American and European species. It is commonly known as the "nose fly," because the female fly forceably "strikes" the animal in the region of the nose, where it attaches its black eggs to the fine hairs of the lips or may even thrust the screw-like stalks, with which the eggs are provided,

Fig. 130

Fig. 131

Fig. 130.—Newly emerged larva of the horse botfly. × 60.
Fig. 131.—Larva of *Gasterophilus intestinalis* horsebot. × 4.

directly into the tender skin. Because of the orange-red terminal segments, this fly is also known as the "redtailed bot."

The fully grown larvae have the habit of moving from the stomach during the early spring and attaching close to the anus before finally dropping to the ground.

Gasterophilus nasalis (Linn.) [*G. veterinus* (Clark)] (Fig. 129c) is the chin fly or throat botfly, also a widely distributed species said to be especially abundant in the Rocky Mountain region. This fly is very annoying to horses, since its eggs are attached to hairs under the jaws, and when the fly darts at the throat, it causes the animals to throw their heads up as though struck under the chin. Egg deposition takes place during

late spring and early summer. Unlike *G. intestinalis* (DeGeer) moisture is not required for the liberation of the larvae. The larvae hatch in from four to five days. The newly hatched larvae travel along the jaw and enter the mouth between the lips. There seems to be no tendency to burrow through the skin of the throat. From the mouth of the horse the larvae travel to their preferred site in the alimentary tract, the pyloric portion of the stomach and the anterior portion of the duodenum

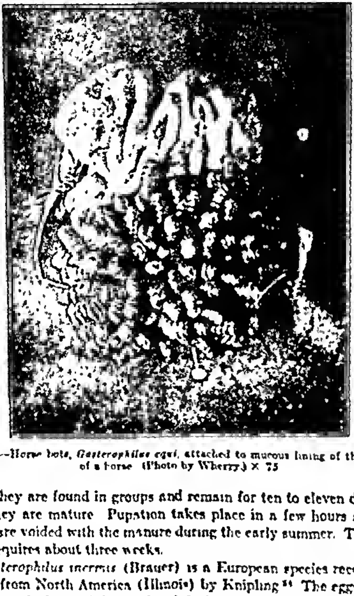

FIG. 137.—Horse bots, *Gasterophilus equi*, attached to mucous lining of the stomach of a horse. (Photo by Wherry.) × .75

where they are found in groups and remain for ten to eleven days, i.e., until they are mature. Pupation takes place in a few hours after the larvae are voided with the manure during the early summer. The pupal stage requires about three weeks.

Gasterophilus inermis (Brauer) is a European species recently reported from North America (Illinois) by Knipling.[11] The eggs are deposited on the hairs of the cheeks of the host and, according to Knipling, when hatched the larvae penetrate the epidermis and work their way

under it until the mouth is reached, thence after molting in the epithelial layer of the cheek they migrate to the rectum, where they remain until fully mature. The larvae drop to the ground and pupate as do other bots. The pupal period is 21 days in the case of Knipling's material. The adult is small, and "densely covered with silvery to yellowish hair, contrasting with the more or less orange-colored hair in *G. haemorrhoidalis*, *G. nasalis* and *G. intestinalis*."

Gasterophilus pecorum (Fabr.) is a European and African species which does not occur in the United States. It is said to deposit its eggs on the food of the host animal and on near-by objects. The larvae burrow into the mucous membrane of the mouth, migrating soon to the stomach and rectum.

Pathogenesis.—While a moderate infestation of bots will give no outward indications, a heavy infestation will be indicated by digestive disorders (which may of course be traceable to other causes as well). The discovery of bots in the manure is sufficient evidence. A light infestation is probably of no consequence—there are indeed some individuals who erroneously maintain that a horse must have at least a few bots in order to be well.

The injury which bots produce is: (1) abstraction of nutriment, both from the stomach and its contents; (2) obstruction to the food passing from the stomach to the intestine, particularly when the larvae are in or near the pylorus; (3) irritation and injury to the mucous membrane of the stomach (Fig. 132) due to the penetration of the oral hooklets; (4) irritation of the intestine, rectum and anus in passage.

Treatment.—Although carbon disulphide had been in use for many years in Europe as a remedy for horse bots, no wide use was made of this chemical for this purpose in the United States until after the experimental work of Hall [35] in 1917. The treatment should be administered only by veterinarians. After preparation of the animal by fasting it for 18 hours (water may be allowed), the chemical is administered in gelatine capsules at the rate of 1.5 fluid drams for each 250 pounds of weight. The bots begin to appear in the animal's droppings in five or six hours. Purgatives should not be used in this treatment.

Gasterophilidae as human parasites.—The larvae of the horse botflies burrow freely as already explained and may cause a form of creeping *cutaneous myiasis* in human beings. *Gasterophilus intestinalis* (DeGeer) is the species usually involved.[36] The course made by these creeping larvae is quite tortuous and plainly visible. The infection causes severe itching. The larvae, which measure from 1 to 2 mm. in length, can be easily extracted surgically.

Oestrid flies of cattle and sheep (Oestridae).—These are robust, strong-flying flies about the size of a honeybee, the mouth parts are rudi-

mentary, the antennae are three-jointed and short, sunken in grooves, the arista are bare, the abdomen is conical, not elongate, genitalia hidden. Curran states that the first vein ends beyond the middle of the wing, the auxiliary vein being long and ending in the costa, the fourth vein ending before the apex of the wing, close to the third vein; the squamae are large. The *Oestridae* include only four genera, viz.: *Oestrus*, which includes the head maggots of sheep; *Cephalemya*, the head maggots of deer; *Hypoderma*, the grubs of cattle; *Oedamagena*, the bots of reindeer.

Cattle grubs or ox warbles, as they are also called, are the larvae of flies belonging to the genus *Hypoderma*, the heel flies. Although the normal host is cattle, horses and humans are occasionally parasitized. Persons dealing with cattle are familiar with the tumorous swellings on

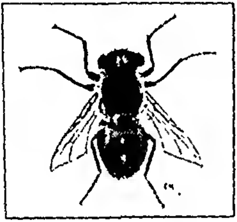

FIG 133

FIG 134

FIG 133.—The common cattle grub, or heel fly, *Hypoderma lineata* (Adapted after Hearle)

FIG 134.—Larva or grub of the ox warble fly, *Hypoderma lineata*, × 1.3

the backs of cattle during the late winter and early spring, and most stockmen have squeezed out the large grubs which inhabit these tumors There are two well-known species. *Hypoderma lineata* (de Villers), widely distributed in the United States, as well as Europe and Asia, *Hypoderma bovis* (DeGeer), less widely distributed and more northerly in its occurrence [37] in the United States, particularly the New England states.

Hypoderma bovis (DeGeer) is the larger of the two species, measuring about 15 mm in length, while *H lineata* (de Villers) measures about 13 mm. The former has the thorax covered with dense yellow hairs in front and black ones behind, with the terminal yellow hairs on the abdomen, while the latter [*H lineata* (de Villers) (Fig 133)] has a fairly uniform hairy covering of mixed brownish black and white with four

prominent smooth and polished lines on the thorax, the hairs of the terminal segment of the abdomen being reddish orange. The full-grown larvae are easily distinguished by examination of the spiny armature—thus *H. bovis* (DeGeer) has the last two segments entirely devoid of spines, while *H. lineata* (de Villers) has only the last one smooth. It may also be said that the full-grown larva of the former measures from 27 to 28 mm. in length and the latter about 25 mm. (Fig. 134).

Life history and habits.—The eggs of both species are laid on the hairs of cattle, *H. lineata* (de Villers), attaching as many as a dozen in a row to a single hair, while *H. bovis* (DeGeer) is said to attach but a single egg to a hair. As many as 800 eggs, it is stated, may be laid by a female of either species.* The eggs are evidently deposited by preference on the legs from the hock to the knee of the standing animal, but in recumbent animals the eggs may be attached to the hairs of other parts of the body close to the ground. Although no pain is inflicted at the time of oviposition, cattle become terror-stricken when the fly is discovered and gallop madly for water or shade in which to stand to escape the enemy. This is termed "gadding" and often spreads to the whole herd.

The eggs of both species hatch within a week and the tiny armored larvae crawl down the hairs of the host and bore either directly into the skin or into the hair follicles.[38] Knipling's [39] studies indicate that there are only three stages, although others have suggested there might be four or five.

Bishopp, Laake and Wells [40] state that the eggs are ordinarily deposited only on sunny days, although *H. bovis* (DeGeer) may continue to oviposit during cloudy periods. A stiff breeze apparently deters the flies, although egg deposition was observed at temperatures as low as 40° F. The eggs hatch in from three to four days and the larvae penetrate the skin, causing considerable irritation. The larvae then work upwards between the muscles and in a few months thereafter are found in the abdominal and chest cavities of the host. The above authors state further, "During the following seven or eight months they constantly burrow about over the surface of the paunch, intestines, spleen, and other organs. Grubs are especially numerous between the muscular and mucous layers of the oesophagus or gullet. The grubs in these situations are slender and their length ranges from about one-tenth to about two-thirds of an inch. In the fall, winter and spring the grubs migrate through the muscular tissues of the back and in a short time reach the under surface of the skin. During this last journey some of them enter the spinal canal and may burrow along the spinal cord for considerable distances. Soon

* Warburton (1922) has presented a most satisfactory account of "The Warble-flies of Cattle" in *Parasitology*, vol. 14, nos. 3 and 4, pp. 322–341.

after the skin is reached the grub cuts a minute hole through to the surface. At this time it is still slender and white and about two-thirds of an inch long, and is smooth except for small spines at each end. From one to five days later the grub molts for the third time." Upon emerging "from this molt the skin is closely set with spines. The body of the host now begins to isolate the invading parasite by forming a pocket or cyst around it. The growth of the grub from this time on is rather rapid, and a fourth molt occurs about 25 days after the third. In this last stage of its development the color gradually darkens, first becoming yellow, then brown, and finally almost black. During this entire development beneath the skin a breathing hole is kept open to the surface, and the grub lies with its two breathing pores, which are located on the posterior end, applied rather closely to the opening in the skin. As growth proceeds the hole in the skin is gradually enlarged." In late spring and early summer "at the end of the period of development in the back, which requires from 35 to 89 days, growth is complete, and the repulsive, spiny grub works its way out and falls to the ground." There the larvae crawl away into the loose earth or debris, becoming rapidly dark brown to black in pupation, and in from four to five weeks emerge as warble flies. The complete life cycle requires about a year.

The warbles begin to appear in the backs of cattle in some parts of California about January first, and Warburton reports mid-February as the time when the indications of newly forming dorsal tumors are most numerous in England.

Injury done.—The injury done by the warbles is first that of *irritation* caused by their migrations in the body of the animal and later in their emergence from beneath the skin; secondly, the escape of the larva from the tumor leaves an open, running wound which persists for a long time and is attractive to screwworm flies and other tormenting insects. The direct pathogenesis is of minor importance, however, in the face of the economic loss produced by this insect.

Economic losses.—The economic losses produced are: (1) Reduction in milk secretion, which is estimated at from 10 to 20 per cent of the normal yield. (2) Loss of flesh due to the wild endeavor of the animals to escape from the flies and the irritating larvae (which is pointed out by Holstein: "A cow quietly grazing will suddenly spring forward, throw up her tail, and make for the nearest water at a headlong gait. Seemingly deprived at the moment of every instinct except the desire to escape, she will rush over a high bluff on the way, often being killed by the fall. This, with miring in water holes and the fact that cattle are prevented from feeding, causes the loss"). (3) Depreciation of the value of the carcass as flesh, which becomes greenish yellow and jelly-like in appearance at the points where the grubs are located, and is not fit for

consumption. (4) Injury produced to the hide which becomes "grubby," full of holes, where the grubs have emerged (Fig. 135).

The following is quoted from Tanners' Work for October, 1913:

"The case is recorded hy Boas of Denmark of a cow which remained in poor condition and gave 22 pounds of milk per day. Forty-six grubs were extracted

the fall. In this case the loss of milk due to the grub infestation was 25 per cent. The loss in flesh on account of gruhs has heen variously estimated at from \$1.00 to \$5.00 or more per head. If we assume that 25 per cent of all of the cattle in the United States are more or less infested with grubs, a quite con-

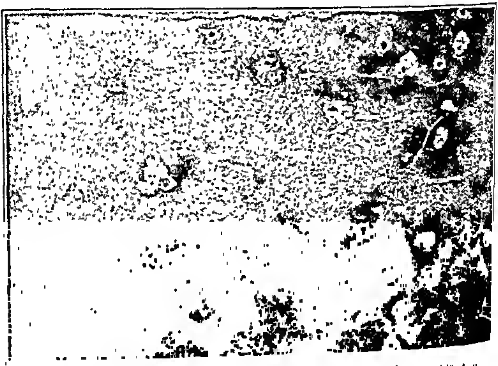

Fig. 135.—A piece of sole leather 21 × 31.5 cm. showing work of ox warble.

servative estimate, 50 per cent probably being nearer the actual percentage, the loss in flesb on account of grubs amounts to from \$15,000,000 to \$75,000,000 a year, the total number of cattle in the United States being calculated as approximately 60,000,000. If we also assume that infested milch cows lose 10 per cent in milk production and that 25 per cent of the 20,000,000 milch cows in the United States are affected, there should be added to the account a loss of not less than \$30,000,000 per year.

"As to the loss in hides it is stated by European tanners that a grubby hide is, on the average, less in value by one-third than a perfect hide, but for this country I have no definite information other than that grubby hides in the green state are commonly valued at one cent a pound less than perfect hides. On this basis the depreciation in value of a hide of average weight of 65 pounds, if grub-infested, would be 65 cents and the depreciation in the value of the estimated 15,000,000 grubby cattle of the United States so far as their hides

are concerned thus amounts to $9,750,000. It is, however, quite probable that the actual loss in the value of hides when made into leather is much greater than this.

"Without including the loss on account of the direct damage to beef carcasses from the presence of grubs, we may, on the basis of the foregoing, estimate the total loss from grubs in the United States in round numbers at from $55,000,000 to $120,000,000 per year."

Treatment.—The tumors in which the grubs occur may be treated with kerosene, benzine, turpentine or carbolic acid, a few drops of which are introduced into the opening by means of a machinist's oiler, or merely smeared over the surface. Ointments of sulphur and vaseline are also serviceable. These remedies are objectionable inasmuch as the grubs are not eliminated, dying within the tumor where they must be slowly absorbed and serious abscesses may result.

A better method is to remove the grubs bodily, which can easily be done by squeezing them out if the grubs are about ready to leave the tumor. If not easily squeezed out, a forceps with slender blades may be introduced into the opening, the grub grasped and eliminated. In some cases the use of a lancet may be needed to widen the opening in the tumor. The use of a properly constructed suction syringe applied when the grubs are "ripe" would no doubt give good results.

After removal the grubs must be destroyed to prevent further metamorphosis, and the wound should be treated with a carbolated salve.

Hearle [41] reports that derris as a wash has proved effective in large-scale experiments in several countries, including Canada. The formula recommended is standardized derris powder one pound, soft soap one-quarter pound, water one gallon. The soft soap is boiled in a quart of water, and when cooled a little is poured into the derris powder in a bucket and mixed into a paste. Cold water and the remainder of the soap solution are then added slowly while stirring, to make up one gallon, and the mixture is ready for use. Standardized derris warble-fly powders ready for use are sold commercially. Before application the derris wash must be agitated frequently to ensure a good mixture. Although the keeping qualities are good if the liquid is placed in a well-stoppered container, it is advisable to prepare only an amount sufficient for immediate application. Where infestation is heavy, the wash should be liberally applied to the backs of the animals with a soft cloth or a worn stable brush, care being taken to cover completely the area affected by the grubs. In many cases, however, it is more economical to pour a little derris wash from a bottle on to each cyst, and to rub it in with the fingers. In the case of animals that are not stall-tied, a crush or dehorning chute is an aid to handling and treating them.

The date for the first application of the derris wash, varying in dif-

ferent parts of the Dominion, is in early spring when the swellings in the backs of the animals caused by the grubs first become conspicuous. In the interior of British Columbia this treatment is given in mid-February; in the prairie Provinces and eastern Canada, about the third week in March. The second and third applications are made after intervals of 28 days, and the fourth after a further interval of about 35 days. A fifth dressing 35 days after the fourth is necessary in milder regions such as the interior of British Columbia, where the first application is made in mid-February. The intervals between the third and fourth, and fourth and fifth dressings are longer than between the preceding ones, being timed to accord with the larval development of *Hypoderma bovis* (DeGeer).

With regard to the treatment of beef herds for *H. lineata* (de Villers) during winter and early spring, the main objection of many ranchers is that working cattle through a chute endangers the calf crop. In our experience these fears are baseless. Ice is a more serious menace, but the danger to stock from slipping may largely be overcome by sanding the yards. The April treatment can be combined with dehorning, if this is practiced.

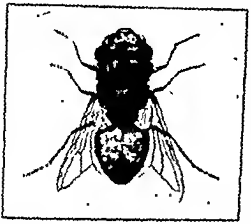

FIG. 136.—The sheep botfly or head maggot fly, *Oestrus ovis* (Adapted after Hearle.)

The Caribou warble fly is *Oedemagena tarandi* (Linn.) and is widely distributed over the range of its host both in northern Europe and northern North America. Hearle (loc. cit.) states that the fly is yellowish orange in color and has a bee-like appearance. The life history resembles that of the warble fly of cattle.

Sheep bots or head maggots.—*Oestrus ovis* Linn. is a very widely distributed species. The fly (Fig. 136) is somewhat more than half the size of the honeybee; it is yellow to brownish gray in color and hairy. The abdomen is variegated with brown and straw yellow; the feet are brown. It is further described by Osborn as follows:

"The ... are extremely ... anterior ar... small eyelets are distinctly visible on the top of the head. It has no mouth ... cannot, therefore, take any nourishment. The wings are transparent and extend beyond the body, and the winglets (calypteres) which are quite large and white, cover entirely the poisers. It is quite lazy and, except when attempting to deposit its eggs, the wings are seldom used."

Life history.—The head maggot fly deposits living young from early summer to autumn in the nostrils of sheep and goats and may also attack human beings. These at once begin to migrate up the nasal passages, working their way into the nasal and frontal sinuses often as far as the base of the horns in rams and attach themselves to the mucous membranes. Here numbers of these whitish grubs may be found wedged in closely in various conditions of development. The posterior ends which are unattached present conspicuous spiracles. The grubs reach full growth with a length of from 25 to 30 mm. by the following spring—a larval period of from eight to ten months. At the end of this time they let go, wriggling their way out of the nostrils, fall to the ground, bury themselves in the earth and pupate in a few hours. The pupal period lasts from three to six weeks and over.

Symptoms.—In the presence of the fly the sheep are very much excited, shake the head, rush with their noses between their fellows, push their noses into the dust, snort and otherwise indicate that they are trying to escape something that persists in entering the nostrils. Once infected there is a purulent discharge from the nostrils, vigorous shaking of the head, and perhaps the occasional discharge of a maggot, loss of appetite, grating of the teeth and, when the animal walks, the fore feet are lifted in a pawing movement.

The great majority of the cases do not result fatally, but death often comes in a week or less after the appearance of aggravated symptoms.

Grub-in-the-head is distinguished from "gid," caused by a larval tapeworm, *Multiceps multiceps* (Leske) [*Coenurus cerebralis* (Batsch)], in that the former is always associated with purulent discharges from the nostrils, absent in the latter, and that the symptoms of the former [illegible]

infection is commonly known as "snotty nose."

Treatment.—Materials such as snuff, pepper, etc , may be introduced into the nostrils or sprinkled among the flock, to induce violent sneezing, which causes the expulsion of many of the larger grubs. Law recommends the injection of benzine, lifting the sheep's nose somewhat and pouring into the nostrils a teaspoonful of the remedy for each nostril. The lower nostril into which the benzine is poured is held shut for thirty seconds; the other side is then turned and the treatment repeated. The application is repeated daily or more often until the maggots are all expelled.

Prevention.—Use of "salt logs" in sheep pastures is made by some sheep raisers. These logs are made by boring two-inch holes at intervals of about six inches along the length on top. Salt is placed into these holes, which are kept about half full, and in turn the edges of the holes are

repeatedly smeared with pine tar, or other repellent material. In endeavoring to reach the salt the sheep involuntarily smears its nose with the substance, which protects it to some extent against the head maggot fly.

Head maggot of deer.—The black-tailed deer (*Odocoileus columbianus* Richardson) and other species of deer and elk are commonly affected with head maggots or nose maggots, species of the genus *Cephalemya*, e.g., *Cephalemya pratti* (Hunter). The following figure (Fig. 137) illustrates the fact that the larvae crowd into the sinuses and that there are all sizes, from very young to fully grown, present at the same time. *C. trompe* (Linn.) occurs in the caribou of both Europe and America, while the camels of Egypt are affected by *C. maculata* (Wied).

Head maggot of horses.—An important species of head maggot attacking horses in Russia and parts of Europe and in Egypt is *Rhinoestrus purpureus* (Brauer). Its habits are said to be similar to

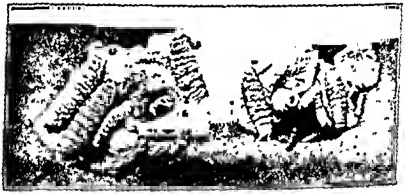

Fig. 137.—Head maggots attached to tissue in nasal sinuses of the deer. × 6

those of *Oestrus ovis* Linn. Like other species of related genera it may attack man either in the nose or eye.

Rodent bots.—The larvae of the family Cuterebridae are parasitic upon rodents, notably wild and domestic rabbits, and mice which are commonly severely infested with skin tumors in which lie the large larvae of *Cuterebra cuniculi* (Clark), *C. tenebrosa* Coq., and *C. emasculator* Fitch, the emasculating, scrotum-inhabiting bot of squirrels. The adult flies are robust and bumblebee-like, having the scutellum elongate, the arista plumose or pectinate, the oral opening large, and the palpi small. There are four genera in this family, one of which includes the human botfly, *Dermatobia hominis* (Linn.); the other three, *Cuterebra*, *Pseudogametes* and *Rogenhofera*, are parasitic on rodents.

Warbles in humans.—Humans, notably in Central and South America, Mexico and other tropical countries, are rather commonly affected with warbles (bots), traceable to one of several species of oestrids,

notably *Dermatobia hominis* (Linn.) {*Dermatobia noxialis* Brauer = *Dermatobia cyaniventris* (Macq.)}, *Hypoderma lineata* (de Vill.), and *H. bovis* (DeGeer) (see previous pages).

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CHAPTER XIX

LOUSE FLIES

ORDER DIPTERA (PUPIPARA) FAMILY HIPPOBOSCIDAE

Characteristics of Hippoboscidae.—The bloodsucking parasitic flies belonging to the family Hippoboscidae are characterized by Williston [1] as follows:

"Head flattened, usually attached to an emargination of the thorax; face short, palpi forming a sheath for the proboscis, not projecting in front of the head; antennae inserted in pits or depressions near the border of the mouth, apparently one-jointed, with or without a terminal bristle or long hairs. Eyes round or oval, ocelli present or absent. Thorax flattened, leathery in appearance; scutellum broad and short. Halteres small or rudimentary. Abdomen sac-like, leathery in appearance, the sutures indistinct. Legs short and strong, broadly separated by the sternum, tarsi short; claws strong and often denticulated. Wings present or absent." They are all parasitic in the adult stage upon birds or mammals. The larvae are pupiparous, but pass nearly the whole of this stage within the abdomen of the parent, being extruded when nearly ready to transform into the mature fly.

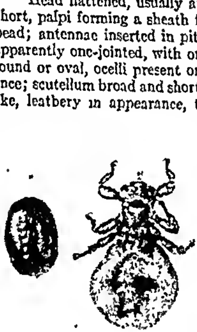

FIG. 138.—The sheep tick or louse fly, *Melophagus ovinus*. Pupa (left), adult (right). × 4 5.

The sheep "tick" or ked, *Melophagus ovinus* (Linn), is a wingless bloodsucking species, reddish brown in color, about 5 to 7 mm. in length, parasitic on sheep and goats. The head is short and sunken into the thorax, the body sac-like, leathery and spiny. (Fig 138.)

Life history.—The eggs are retained within the body of the female ked where the larvae develop in seven days and are extruded fully grown ready to pupate. The extruded larva during the course of a few hours becomes chestnut brown in color, the secretion with which it is covered hardens and serves to glue the pupa firmly to the wool of the host. The pupae are commonly found on infested animals in the region of the shoulders, thighs and belly. Pupae may be found on sheep at all times

of the year, though the time required for development in the winter is longer than in the summer. Swingle,[2] who has carried on most careful observations on this insect, states that pupae require from 19 to 23 days to hatch in the summer, whereas 19 to 36 days are required during the winter on sheep kept in the barn and probably 40 to 45 days on sheep out of doors. The time required for the females to reach sexual maturity is from 14 to 30 days and over, when they begin extruding young at the rate of one about every seven to eight days. Swingle (loc. cit.) regards about four months as the average life of a sheep tick, during which from 10 to 12 pupae are deposited.

The whole life of the ked is spent on the host; when off the sheep the insects die in from two to eight days, the majority dying in about four days.

Damage done.—The presence of a few louse flies on the bodies of sheep does not materially affect them. Ordinarily the presence of the insect is indicated by the fact that the animal rubs itself vigorously, bites the wool and scratches. Badly infested animals show emaciation and general unthriftiness. The injury to lambs is especially marked.

Control.—Since the principal time for migration from the sheep to the lambs is at shearing when the insects are taken off the hosts with the wool, it is wise to take particular pains at this time to store the wool at some distance from the lambs. Inasmuch as the "ticks" die within a week when away from the host and cannot well crawl any great distance, the above suggestion is well worth considering. Swingle states that "sheep free from 'ticks' can be kept for months beside a heavily infested one with a tight partition only three feet high between them without becoming infested . . . A bunch of females placed in the wool of a sheep will be found in practically the same place for two days. Males, however, are more inclined to migrate." A flock of sheep once freed from "ticks" can therefore be kept clean unless infested animals are introduced.

The writer has reasons to doubt the efficiency of "lime-sulphur" sheep-dip for the sheep "tick." Tobacco dips when used in 0.07 per cent solution will eradicate sheep "ticks" according to Imes[3] if two dippings are given with an interval of 24 to 28 days between dippings.

Louse flies of deer.—*Lipoptena depressa* (Say) and *Lipoptena ferrisi* Bequaert (*L. subulata* Coq.) are common parasites of deer on the Pacific coast. These species are smaller than *Melophagus ovinus* (Linn.), otherwise resembling it; they are wingless when established on the host but have well-developed filmy wings on emergence. (Fig. 139.) These parasites have been found in chains, three or four attached to each other, the first fly drawing blood from the host, the second with its proboscis thrust into the abdomen (dorsally) of the first, the third drawing on the

second and so on to the last individual. *Lipoptena cervi* (Linn.), known as the "deer ked," is reported to be a common species on European deer, and according to Bequaert [4] has become naturalized in a few localities of the northeastern United States on the Virginia white-tailed deer. *Lipoptena mazamae* Rondani occurs on deer in South and Central America and in the southeastern United States.

The Genus Hippobosca

The eight species of the genus *Hippobosca* recognized as valid by Bequaert [5] are found in Africa; four extend into the Oriental region and two have entered Europe.

The wings are always well developed in the genus and are functional throughout adult life. With the exception of the ostrich louse fly, *Hippobosca struthionis* O. E. Janson, the species of this genus are ectoparasites of mammals. Except for *H. struthionis* O. E. Janson, host specificity is

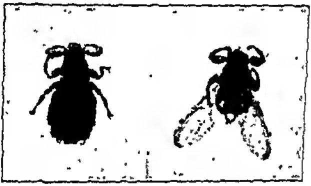

FIG. 139.—Louse fly of the deer, or deer tick, *Lipoptena depressa*, showing wingless and winged form. × 5.

not very pronounced. The full-grown larvae of *Hippobosca* are evidently not placed among the hairs of the host, but according to Bequaert they are deposited in cracks of walls, boles of trees, or on the ground.

Hippobosca equina Linn. is a common species in England and is known as the "forest-fly." It is usually found on horses, mules and donkeys, sometimes on cattle and other animals. *H. rufipes* v. Olfers is also primarily a parasite of equines and occurs in South Africa.

Hippobosca capensis v. Olfers is a louse fly reported by Bequaert to be commonly found on domestic dogs, especially on the pariah dog of India. It is also common in many parts of the Mediterranean region.

Hippobosca maculata Leach occurs on domestic cattle and equines and is widespread in distribution. *H. fulva* Austen off the hartebeest is known only from its type locality, northeastern Rhodesia. *H. hirsuta* Austen is reported to be a parasite of the water bucks and allied antelopes of Africa.

Hippobosca struthionis O. E. Janson is specific to the ostrich and is abundant on its host in South Africa. *H. camelina* Leach is a parasite of the camel and dromedary.

Louse Flies of Birds

The pigeon fly, *Pseudolynchia canariensis* (Macq.) [*Lynchia maura* (Bigot) = *Olfersia maura* Bigot], is an important parasite of domestic pigeons throughout the tropics and warmer regions of the world. It is found throughout the south of the United States and California. The dark brown flies have long wings, 6.5 to 7.5 mm., and are able to fly swiftly from the host but usually alight near by. They move about swiftly among the feathers of the host and bite and suck blood from parts that are not well feathered.

The mature larvae, at first pale yellow and later jet-black in color, are deposited on the body of the bird while it is quiet, but they soon roll off and collect in the nests. Bishopp [6] gives the duration of the pupal stage at from 29 to 31 days when the mean daily temperature is about 73° F. Thus the thorough and regular cleaning of the nests at intervals not to exceed 25 days is probably the most important single step in control. The pupae are very resistant, hence ordinary insecticides are of little use. Bishopp [6] states that "one of the most effective and easily applied treatments for squabs is *fresh* pyrethrum powder, one to three pinches, depending upon the size of the squab, scattered among the feathers." Flies in cages and buildings may be destroyed by using a spray of kerosene extract of pyrethrum, i e., ordinary fly spray.

In addition to its parasitic habits the pigeon fly is the vector of pigeon malaria caused by *Haemoproteus columbae* Celli and San Felice.[7]

Pseudolynchia brunnea (Latreille), also referred to as the pigeon louse fly, is regarded as a distinct species by Bequaert.[8] It is very dark brown in color, often nearly black.

Lynchia hirsuta Ferris is a common and abundant parasite of the Californian valley quail, *Lophortyx californica californica* Shaw, and has been shown by O'Roke [9] to be a vector of quail malaria caused by *Haemoproteus lophortyx* O'Roke.

Stilbometopa impressa (Bigot) is also a parasite of the Californian valley quail. *Lynchia fusca* (Macquart) is a parasite of the owl, *Bubo virginianus pacificus* Cassin, in California and has been experimentally shown to be a vector of quail malaria by Herms and Kadner.[10] The flies feed readily on quail and deposit their mature larvae freely on these birds. The incubation period of the infection in the fly was found to be from 9 to 13 days and in the quail about 25 days.

Lynchia americana (Leach) is characteristically a parasite of owls in North America.[11]

Bat flies are pupiparons bloodsucking parasites belonging to the family Streblidae. Except for one known species occurring on doves and parrots (*Strebla avium* Macq.) they are all parasitic on bats in tropical and sub-tropical climates. The members of the family may be separated from the Hippoboscidae by the large leaf-like palpi which project in front of the head and do not form a sheath for the proboscis. They differ from the Nycteribiidae (the spider-like bat flies) in that they do not have the head resting in a groove on the dorsum of the thorax. Little is known about the life history of these insects. The species of the family Streblidae have been reviewed by Kessel.[12]

Spider-like bat flies belong to the family Nycteribiidae. They are very small (2 to 3 mm. long) wingless spider-like parasites of bats. Except for a very few species described from North and South America, they are primarily parasites of Old World bats. Ferris [13] has reviewed the New World species.

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CHAPTER XX

FLEAS

ORDER SIPHONAPTERA

General morphology.—Fleas are laterally compressed, wingless, highly sclerotized, small, bloodsucking ectoparasites belonging to the order Siphonaptera. In size the commoner species vary from 1.5 to 4 mm. in length. The males are as a rule somewhat (often considerably) smaller than the females. The posterior pair of legs is strikingly adapted for leaping. Chigoe fleas are able to burrow partly into the skin of the host, hence are largely sessile.

The head bears the mouth parts (Fig. 28) of which the pair of triangular blade-like maxillae with maxillary palpi are conspicuous elements. The head also bears the inconspicuous annulated knob-like antennae which lie in grooves. Compound eyes are lacking, but simple eyes may or may not be present. Bristles near the eyes (ocular bristles) may be used in classification. In some species a conspicuous row of bold spines (*ctenidium*) are located just above the mouth parts (*genal ctenidia*). (Fig. 140)

The thorax presents a number of sclerites (plates), the dorsal being known as *tergites*, the ventral as *sternites*, the lateral plates as *pleurites*. As in other insects the thorax is divided into three segments, pro-, meso-, and metathorax, each of which bears a row of spines situated posteriorly and pointed backward. In certain species the pronotum bears a row of heavy spines known as the *pronotal ctenidium*.

The abdomen consists of ten segments which, like the thoracic segments, are made up of plates, tergites, sternites, and concealed pleurites; rows of backward-pointing spines are present. On the apical edge of the seventh tergite occur the *antepygidial* bristles. The ninth *tergite* consists of a peculiar pincushion-like structure known as the *pygidium* which is probably a sensory organ.

The male terminalia are particularly important in classification. Among the parts to be observed are the *claspers*, movable and non-movable portions, and the *manubrium*. (Fig. 141.) In cleared specimens the spring-like *penis* may be seen lying in the region of the fifth and sixth segments which in copulation projects out from between the upper and lower claspers. The females possess a sacculated spermatheca, situated in the region of the eighth or ninth segment and easily visible in cleared

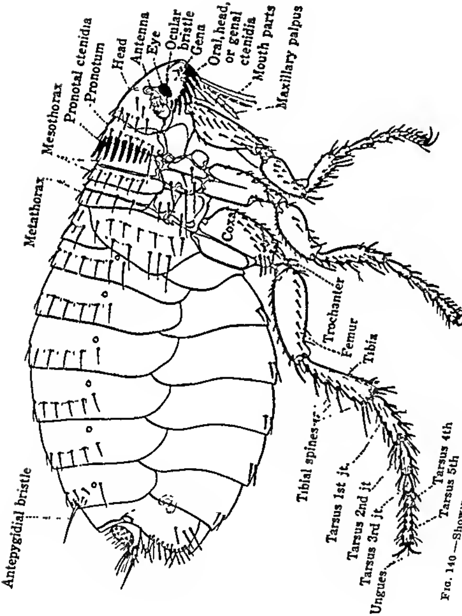

FIG. 140 —Showing certain characters used in the identification of Siphonaptera, fem

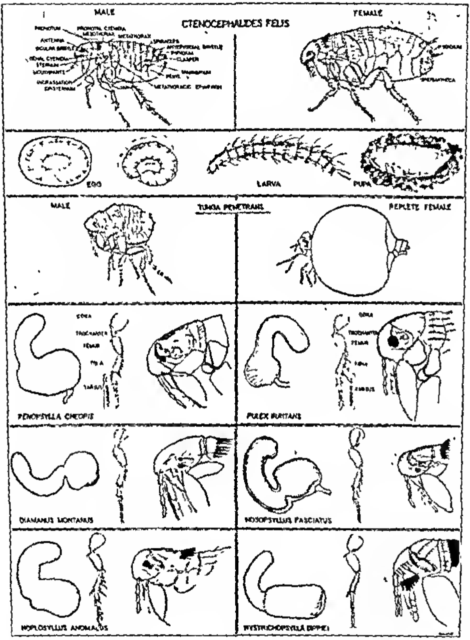

FIG. 141.—Showing structural details used in the classification of Siphonaptera. Also shows life history.

specimens. Some species have two spermathecae. This organ is characteristic for many species and is, therefore, an important taxonomic character. (Figs. 141 and 142.)

The legs consist of five joints, viz.: the *coxa*, the joint nearest the body; the *trochanter*, a very small segment; the *femur;* the *tibia* (strongly spined); and the five-jointed *tarsus* terminating in a pair of *ungues* or claws which may be considered as a sixth segment.

Digestive tract.—The *pharynx* or buccal cavity is situated within the head, receiving the food from the mouth parts. The *hypopharynx* is a small, ventrally concave sclerite prolonged anteriorly where it is perforated by the salivary duct. Then follows the *aspiratory pharynx* which by means of powerful muscles aspirates the blood from the wound and on relaxation carries it to the long narrow *oesophagus* which begins in the region of the brain and passes through the circumoesophageal ring.

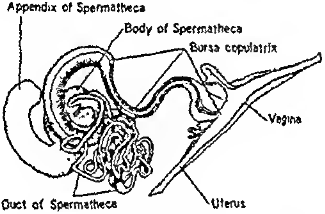

FIG. 142.—Showing copulatory organs of *Nosopsyllus fasciatus*, female. (After Fox)

The oesophagus opens into the stomach through the bulbous *proventriculus* which is provided internally with radially arranged (seven rows) hair-like chitin-covered processes (Fig. 144) which, when the encircling bands of muscles contract, cause them to meet and form a valve, thus preventing regurgitation from the stomach. The *stomach* is a capacious distensible organ nearly as long as the abdomen emptying into the short *intestine* which in turn empties into the wide *rectum* with its six *rectal glands.* Where the stomach joins the intestine, four filamentous *Malpighian tubules* arise.

Life history.—The eggs of a flea are comparatively large (.5 mm. long), glistening white and rounded at both ends. Comparatively few, from 3 to 18, are deposited at one laying; however, during the entire lifetime of a female the number may be quite considerable. Bacot (1914) [1] records a total of 448 eggs over a period of 196 days deposited by a single female human flea, *Pulex irritans* Linn. Most species deposit dry eggs which do not become attached to the hairs of the host even though ovi-

position takes place on the host. Other species of fleas seldom oviposit among the hairs of the host, preferring the nests of the hosts where flea excrement occurs. Captured fleas will readily oviposit in glass vials or other receptacles in which they are trapped. If deposited on a dog or cat the eggs fall off readily when the animal stretches and shakes itself; thus myriads of eggs may be found on the sleeping-mat of a flea-infested animal. Temperatures of 65° to 80° F. when combined with a fairly high humidity, 70 per cent and over, appear to favor egg laying. The incubation period varies from two to twelve days.

High mean temperature from 35° C. to 37° C. inhibits development, which may account for the fact that the eggs do not hatch well on the host. At a temperature of from 17° C. to 23° C. Mayne (Mitzmain [2]) found that the egg stage lasted from seven to nine days; at from 11° C. to 15° C. it lasted about fourteen days. Atlantic coast observers have found that this stage may be completed in from two to four days.

The embryo is provided with a sharp spine (egg burster) on the head by means of which the eggshell is cut into shreds by a tumbling motion of its inhabitant, which is thus liberated The larvae are very active, slender, 13-segmented, yellowish white maggots, with segmentally arranged bristles. The mouth parts are of the biting type and the newly hatched larvae of some species, e g, *Nosopsyllus fasciatus* (Bosc), may subsist wholly on the feces of the adult fleas. Very little food seems to be necessary for their development, though excrementous matter, e g., feces from rabbits, rats, squirrels and other rodents, also dry blood, sprouting grain, etc, may be used as food. Excessive moisture is certainly detrimental to the life of the larvae, although a high percentage of moisture in the air is needed. The larvae are frequently found in houses in the crevices of the floor under the carpet or matting, also in stables, coops, kennels, nests of rodents, pig pens, etc. When conditions are favorable, the time required for the larval period may be but 9 to 15 days; if unfavorable, it may extend over 200 days. At the end of the active feeding period when full growth has been achieved. the larva enters a quiescent stage, spins a cocoon and pupates. The cocoon is whitish in appearance and so loosely spun that one may see the pupa within it.

The pupal period is influenced by temperature and varies greatly, from as short a period as seven days to nearly a whole year. The life cycle accordingly may vary from as short a time as 18 days to many months.

Mayne (Mitzmain 1910 [3]) observed one individual of the squirrel flea, *Diamanus montanus* (Baker) (*Ceratophyllus acutus* Baker), from the moment the egg was laid to the emergence of the adult flea, securing the following data: incubation period of the egg, 8 days; first instar larva, 6 days; second instar larva, 10 days; third instar larva, 12

days; cocoon (pupal stage), **31 days**; total, 67 days. (Figs. 141 and 143.)

Longevity of fleas.—Bacot (loc. cit.) states that with nearly saturated air at 45° to 50° F. fleas can live for many days unfed. He reports that *Pulex irritans* Linn. survived for 125 days, *Nosopsyllus fasciatus* (Bosc) for 95 days, *Xenopsylla cheopis* (Roth.) for 38 days, *Ctenocephalides canis* (Curt.) for 58 days and *Ceratophyllus gallinae* Schrank, for 127 days. If fed on their natural host, *P. irritans* Linn. may live upwards of 513 days, *N. fasciatus* (Bosc) for 106 days and *X. cheopis* (Roth.), fed on man, 100 days. *Ct. canis* (Curt.) and *C. gallinae* Schrank have lived for periods of 234 and 345 days respectively when fed on man. Thus Bacot indicates that the maximum possible length of life

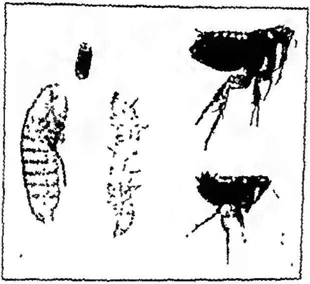

FIG. 143.—*Showing life history of a flea: egg, upper left; larva, center; pupa, lower left; female, upper right; male, lower right.*

of the various species mentioned is 966 days for *Pulex irritans* Linn, 738 days for *Ctenocephalides canis* (Curt.), 680 days for *Nosopsyllus fasciatus* (Bosc), 481 days for *Ceratophyllus gallinae* Schrank, and 376 days for *Xenopsylla cheopis* (Roth.). In a moist medium such as wheat grains and sawdust Mayne (Mitzmain 1910 loc. cit.) has kept squirrel fleas alive from 38 days in one case to 65 days in another, the former a male, and the latter a female. Male rat fleas fed on human blood alone averaged eight and one-half days (maximum 17) of life, and the females 34 4/5 days (maximum 160).

Hosts and occurrence of species.—As will be seen later in this chapter, the rodent fleas are most important from the public health standpoint, and ready transference from host to host of different species adds much to the danger of disease transmission.

While it is true that ordinarily a certain species of flea predominates on a given species of host, e.g., *Ctenocephalides canis* (Curt.) on the dog, and particularly the cat. *Nosopsyllus fasciatus* (Bosc) on the rat in Europe and the United States, *Xenopsylla cheopis* (Roth.) on the rat in Asia, *Ctenopsyllus segnis* (Schön.) on the mouse, *Pulex irritans* Linn. on the human, etc., host specificity in fleas is not strongly marked in many species.

In an unpublished report to the writer on the species of fleas found on rats in San Francisco, Rucker states that a great preponderance of the rat fleas recovered in San Francisco were *Nosopsyllus fasciatus* (Bosc) as based on 10,972 specimens as follows:

Nosopsyllus fasciatus (Bosc)	68.07%
Xenopsylla cheopis (Roth.)...	21.36%
Pulex irritans Linn	5.57%
Ctenopsyllus segnis (Schon.)..	4.48%
Ctenocephalides canis (Curt.)	0.52%

The following tables (Tables IX to XV) adapted after McCoy[4] throw much light on the interchange of hosts and the predominance of species:

TABLE IX

From Brown Rats [*Rattus n. norvegicus* (Erxleben)]

No. of rats combed	*N. fasciatus*		*X. cheopis*		*P. irritans*		*C. segnis*		*Ct. canis*	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
606	370	1253	790	1146	225	425	44	127	13	13

TABLE X

From Black Rats [*Rattus rattus rattus* (Linn.)]

No. of rats combed	*N. fasciatus*		*X. cheopis*		*P. irritans*		*C. segnis*		*Ct. canis*	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
11	7	32	6	5	0	0	4	37	0	2

TABLE XI

From Mice (*Mus musculus* Linn.)

From an unknown number of *Mus musculus* Linn.

	N. fasciatus		*X. cheopis*		*P. irritans*		*C. segnis*		*Ct. canis*	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
	1	5	2	0	0	0	1	10	0	0

TABLE XII

From California Ground Squirrels [*Citellus beecheyi beecheyi* (Richardson)]

No of squirrels combed	*Diamanus montanus*		*Hoplopsyllus anomalus*	
	Male	Female	Male	Female
132	2063	2306	88	140

TABLE XIII

From the Dog (*Canis familiaris* Linn.)

No combed	*Ct canis*		*P. irritans*		*Ct. felis*		*D montanus*	
	Male	Female	Male	Female	Male	Female	Male	Female
4	10	44	8	17	0	1	1	0

TABLE XIV

From the Cat (*Felis domestica* Linn.)

No. combed	*Ctenocephalides felis*	
	Male	Female
2	3	15

TABLE XV

From Man (*Homo sapiens* Linn.)

No of individuals	*P irritans*		*Ct. felis*		*Ct. canis*		*D. montanus*	
	Male	Female	Male	Female	Male	Female	Male	Female
29	117	220	1	0	1	0	1	2

Plague is an acute infectious disease caused by *Pasteurella* (=*Bacterium*) *pestis* (Lehman and Neumann), (Atlas u. Grund. d. Bakt., 1896, p. 194). It is essentially a disease of rodents, usually transmitted by rodent fleas, but it may under certain conditions affect man. The name *bubonic plague* is used when inflammation of lymph glands results and buboes are formed; these are the first foci of the infection and may remain so localized and cause little discomfort. The buboes vary from 2 cm. to 10 cm. in diameter and are usually located in the groin (femoral glands) and axilla (axillary glands). When invasion of the blood stream occurs, a secondary pneumonia may develop and *pneumonic plague* may be produced. This form of plague may be

transmitted from man to man as droplet infection and is not dependent upon either rodents or fleas. Pneumonic plague is almost invariably fatal.

A third type of plague is known as *septicaemic plague*, a fulminating type, due to invasion of the blood stream, which runs a very rapid course; death results before local signs are evident. Wu [5] states that "this fulminating type of plague is met with in pneumonic as well as in bubonic epidemics. Fulminating instances in pneumonic outbreaks are often peculiar to the final stage and are presumably instrumental in bringing about a spontaneous decline of the epidemic as droplet infection is absent, the patients succumbing before cough develops."

The first recorded pandemic of plague according to Wu (loc. cit.) was that of Justinian in the sixth century, starting in Egypt in 542 A.D and spreading to Constantinople It lasted fifty to sixty years, and its victims are estimated at 100,000,000. The second plague pandemic, the "Black Death," took place in the fourteenth century in Europe and claimed 25,000,000 victims or about one-fourth of the population. In Great Britain from half to two-thirds of the people perished. The great plague epidemic of London, 1664–1666, is said to have killed 70,000 persons out of a total population of 450,000. Plague disappeared from England in about 1680, having been almost continuously present for nearly 140 years, with five epidemics

Gradually this infection receded from Europe and the Near East, and as Wu (loc. cit.) points out "the existence of endemic foci, comparable to stagnant pools left behind by the lowering tide, was recognized . . . we now know a whole series of endemic plague foci, usually with epizoötics among the wild rodents situated near or even contiguous with Central Asia . . . the whole of this vast territory with its hosts of wild rodents might be compared with a heap of embers where plague smoulders continuously and from which sparks of infection may dart out now and then in various directions." The present pandemic is believed to have originated in a wild hibernating rodent, the tarbagan (*Arctomys bobac* Schreber) in the interior of China some forty years ago and began as an epidemic in Hongkong in 1894 and was transported along world trade routes to many parts of the globe. The rat, as transported in commerce, constitutes the chief means of spreading the disease, the infection being carried from rat to rat by means of fleas. For this reason plague may appear in n city far removed from the original focus of infection.

The answer to the question, "Is the disease in man and rodents identical?" was not forthcoming until 1894 with the work of Yersin and Kitasato in Hongkong. The former found the organism in the corpses of dead rats and according to Wu gave the first detailed and accurate

description of *Pasteurella pestis*, Yersin calling it Bacille de la peste (Annales de l'Institut Pasteur, Vol. 8, 1894, p. 666). To Kitasato, Wu states, we owe the earliest account of the organism, as he found the plague bacilli in the "finger blood of a patient with axillary bubo."

The disease.—Chun (loc. cit.) gives the period of incubation from two to ten days; the onset usually occurs within a period of three days. Fox in "Insects and Disease of Man," page 294 (P. Blakiston's Son & Co., by permission), describes the disease as follows:

"It develops suddenly with a rapid rise of temperature, reaching 103° or 104° F. in two or three days, after which it is more or less irregular. There is headache, the eyes are injected and the facies are characteristic of extreme illness. Prostration is profound and comes on early. Delirium also appears early. The characteristic lesion of the disease, the bubo, usually is sufficiently pronounced by the second day to be readily detected. The most common site for the bubo is the femoral or inguino-femoral region, then the axillary region, cervical, iliac and popliteal Over the enlarged glands oedema appears and pressure elicits great tenderness. The individual lymph nodes cannot be palpated. This swelling forms the primary bubo Secondary buboes may appear in other parts of the body. In these, the glands are not matted together as in the primary bubo Four forms of skin eruption may be described—a petechial eruption, ecchymoses, a subcuticular mottling, and the so-called plague pustule . . . a bulbous-like formation containing thin, turbid material teeming with plague bacilli It is believed to indicate the original point of inoculation, the flea bite. Extending from this to the nearest lymphatic glands faint red lines indicating lymphangitis may be observed A secondary pneumonia due to the deposit of plague bacilli in the pulmonary tissues may occur In about a week if the patient survives, the bubo breaks down leaving an ulcer which heals slowly."

Fleas as vectors.—Ogata [6] in 1897 came to the conclusion on epidemiological grounds that fleas were the agents of transmission, pointing out that fleas leave the rat as it becomes cold after death and so may transmit the virus direct to man. He pointed out that the flea can ingest plague bacilli while feeding, having produced plague in mice by injecting an emulsion of crushed fleas taken from plague rats.

Simond [7] in 1898 was the first to succeed in transmitting plague from a sick rat to a healthy rat through the agency of infected fleas. Simond's work was discredited for several years, but was successfully repeated by Verjbitski [8] in 1903.

Liston [9] *in 1904, working in Bombay,* came to the following conclusions: (1) There was one flea infesting rats in India far more commonly than did any other, viz., *Xenopsylla cheopis* (Roth.), (2) that these fleas when feeding on a plague rat harbored the plague bacilli in their bodies and that these multiplied therein; (3) that where fatal plague occurred, many of these infected fleas were at large, and (4) that after a local epizoötic of rat plague, man was also found to harbor these rat fleas and might become infected as had the guinea pigs used in the experiment.

The following is a very brief summary of experiments conducted by the Indian Plague Commission before and after its organization in 1905.

In the first instance healthy rats were confined in close proximity to rats which, inoculated with plague, were beginning to succumb to that disease and were artificially infested with rat fleas [*X. cheopis* (Roth.)]. The separate confinement of the rats in each case was so arranged that both contact with and access to all excreta were excluded, although it was provided that the fleas could pass from the inoculated to the healthy rats; this transfer actually did take place, and in many cases these fleas contained virulent plague bacilli; and when healthy nonimmune rats were thus infected they died of plague to the extent of 79 per cent, this extent of infection fell to 38 per cent, when partly immune rats of local origin were employed.

That the plague had originated in the healthy rats through the intermediary of the rat fleas was further demonstrated by the fact that when these were actually transferred from artificially plague-infected to healthy English rats, the disease developed in 61 per cent of the latter.

Further, on constructing a series of miniature houses so as to reproduce the conditions pertaining to ordinary domiciles, it was found that whenever these were so constructed as to admit rats to their roofs, but not to their interiors, guinea pigs confined therein became successively infested with rat fleas and infected by plague, but that in those houses to which rats could not gain access plague was originated in guinea pigs living therein, either by transferring rat fleas to them, derived from plague-infected guinea pigs, or by an accidental admission of rat fleas from other sources. Also, when so confined, guinea pigs had under these conditions died of plague; healthy flea-free guinea pigs, subsequently introduced, became infected, and the infection remained in the place in proportion as the test animals were accessible to, and were found to be infested with, fleas: in other words, that "if the fleas be present, the rate of progress is in direct proportion to the number of fleas present." Further, that when healthy guinea pigs were confined in one of the houses, to the interior of whose roof fleas could not gain access, they became flea-infested and infected when running on the ground, but to a less extent when the cage was placed two inches therefrom, and not at all when it was suspended two feet above it. The fact that infection took place where pigs were located two inches above the ground indicates that contact with infected soil is not necessary for plague to originate, and that "an epizoötic of plague might start without direct contact of healthy with infected animals."

To demonstrate that this communication of plague from guinea pig to guinea pig was through the intermediary of fleas, rat fleas were taken from a morbid guinea pig and allowed to feed through muslin on healthy

animals. The positive outcome of this experiment proved the truth of the above statement.

The state of affairs that existed in actual domiciles in which plague occurred or had existed was next inquired into, advantage being taken of the fact that plague-susceptible guinea pigs would serve as hosts as well as for the collection of fleas.

Guinea pigs free from fleas were introduced into rooms in which persons had died of plague, or from which plague-infected rats had been taken. They were allowed to be at large in these rooms for periods of from 18 to 24 hours. These guinea pigs not only collected the fleas on their bodies, most of which were rat fleas, but 29 per cent of them contracted plague and died of plague within a few days after being restored to ordinary confinement. As before, many of the fleas which they yielded harbored plague bacilli in their stomachs and were capable of infecting additional animals.

Further, after first washing the floors and walls of the rooms with an acid solution of mercuric chloride and so adequately disinfecting them for plague, but not for fleas, and then introducing guinea pigs, these became plague-infected when rat fleas were present.

That the infection was actually due to fleas was also shown by the positive results when fleas collected from rats occurring in plague-infected houses were transferred to healthy rats or guinea pigs in the laboratory. These in due course became infected and died of plague.

Similarly fleas taken from the clean guinea pigs allowed to run in plague-infected houses, and transferred to fresh animals, communicated plague to them in eight out of 40 tests.

In the next place plague-free white rats, guinea pigs and monkeys were placed in enclosures, which precluded contact as well as soil infection in plague-infected rooms, pairs of one animal or another being used in each of the 42 experiments of this class conducted, one individual being confined to a flea-proof receptacle and the other to an adjacent one accessible to these insects (one animal being thus a control). In the latter case plague resulted in four instances, or 10 per cent gave positive results.

As a variation of the same experiments the enclosures for individual animals, while protected from soil or contact infection, were surrounded as a screen to fleas by two and one-half inches of "tanglefoot" or were unprovided with this protection, the "tanglefoot" being replaced by sand. (Twenty-nine experiments were conducted.) In the latter case the animals became infested with fleas, one having as many as 20; seven became fatally infected with plague. In the former, individual fleas were found on only three of the rats and no animals became plague-infected.

Examining the fleas entrapped, 247 in number, it was found that

147 were human fleas, 84 were rat fleas, and 16 cat fleas. Moreover, a large proportion of each kind was examined. No plague bacilli were found in the cat fleas, one only in 85 of the human fleas was infected, and no less than 23 out of 77 of the rat fleas harbored plague organisms.

It was also shown that, when rats in the course of an epizoötic died of plague, the pathological features manifested in their bodies corresponded to those exhibited by artificially rat-flea-infested animals, and hence it was inferred that in nature and under experimental conditions the animals had alike succumbed to a single agency. This similarity especially related to the site in which buboes arose, as in both instances, where the place of inoculation could be observed, it was the same.

Further observations.—Blue [10] reports a number of observations made in San Francisco during 1906, namely, two small boys found the body of a dead rat in an unused cellar; the rat was buried with unusual funeral honors and in forty-eight hours both were taken ill with bubonic plague. Again, a laborer picked up a dead rat with the naked hand and threw it into the bay. He was taken ill with plague three days later. The case of a physician's family is also cited in which foul odors pervaded their second story apartment over a grocery store. On removing the wainscoting around the plumbing to ascertain the cause of the odor, two rat cadavers were found in the hollow wall. In two or three days thereafter the two members of the family who used the room sickened, one dying on the fifth day of cervical bubonic plague. Blue believes that the removal of the wainscoting set free infected rat fleas.

The following instance is reported in the United States Public Health Reports (November 7, 1913, page 2356): a fatal case of plague occurred in Manila (P. I.) in the person of an American, editor of the Manila Daily Bulletin. A plague rat had been found on September 6 in the block adjacent to the one in which the newspaper offices were located. The editor was admitted to the hospital September 19 and died at the Plague Hospital three days later. A mummified rat was found in the desk of the late editor, together with live fleas, *Xenopsylla cheopis* (Roth). Both the fle... and rat revealed bipolar staining organisms, and inoculations into healthy laboratory rats produced typical cases of plague terminating fatally.

That the mummified rat must have been dead at least two weeks and that the live fleas contained plague bacilli suggests "strong proof that plague might be introduced into a country without either the importation of human or rat cases of plague and that fleas might be alone concerned."

Rôle of the flea in plague transmission.—The Indian Plague Commission showed that the average capacity of a flea's stomach [*Xenopsylla cheopis* (Roth.)] was .5 cubic millimeter, and that it might

mine whether or not the results would be constant for any length of time. Eskey points out that there seems to be danger of infection from virulent plague organisms present in the feces of all plague-infected fleas.

Still another possible mode of transmission which applies, however, only to transfer from rodent to rodent, has been suggested by various workers, namely, that of crushing infected fleas with the teeth, with infection through the mucosa of the buccal cavity resulting in lymph-node involvement in the region of the neck.

Ground squirrels and plague.—Plague has been found in a number of species of rodents other than rats. In California the disease was demonstrated in ground squirrels [*Citellus beecheyi beecheyi* (Richardson)] under natural conditions in 1908 by McCoy.[15] According to this author at the time of his writing (1910), about a dozen persons had contracted the disease under circumstances that pointed conclusively to squirrels as the cause. The two species of fleas commonly infesting the ground squirrel in California are *Diamanus montanus* (Baker) (*Ceratophyllus acutus* Baker) and *Hoplopsyllus anomalus* Baker, of which the former is far more numerous. McCoy proved the first-named species a carrier as follows: he inoculated a ground squirrel subcutaneously with a broth culture of *P. pestis* derived from a human case of plague. This squirrel died on the fifth day, but three days before its death, 100 fleas [*D. montanus* (Baker)] were put in the cage with it. The dead animal was removed from the cage while warm, and 27 live fleas taken from its body. Smears made of the crushed bodies of two of these fleas showed an abundance of pest-like bacilli in each. The remaining 25 fleas were put into a clean cage with a healthy squirrel. This animal died of subacute plague 10 days later, the buboes being in the region of the median, posterior inguinal and pelvic glands. A pure culture of *P. pestis* was obtained from the liver. McCoy states that the experiment is conclusive in showing that *D. montanus* (Baker) may convey plague from a sick to a healthy squirrel. The squirrels used in the experiment were kept in quarantine for at least a month prior to their being used, which was necessary to exclude any naturally infected ones. McCoy found the bacilli in squirrel-flea feces four days after removal of the fleas from the host.

Sylvatic (selvatic) plague.—The designation selvatic plague was proposed by Ricardo Jorge (1928) (see Chapter I) for the plague of wild rodents. Fleas play an important rôle in transmission from rodent to rodent and consequently in the endemicity of the disease. It is now known that under certain ecological conditions in vacated squirrel burrows fleas may continue to harbor virulent *P. pestis* for many months thus providing a virtual insectan reservoir for the infection under syl-

vatic conditians. Fleas have been known to survive though starved for more than six months (196 days).

Aside from the matter of flea transmission it is important to bear in mind that the great epidemic of plague in Manchuria resulting in 60,000 deaths in 1910–1911 was af the pneumonic type and sprang from the wild tarbagan, *Arctomys bobac* Schreber (Siberian marmot), which was hunted for its valuable reddish brown fur by numerous Chinese hunters unfamiliar with its dangers. The mountainous partians of Central Asia, i.e., portions of Siberia, Mongalia, Tibet and Manchuria, are regarded as the original home of plague, and the tarbagan as well as its flea parasites play an important rôle as reservoirs of the infection. These large rodents are about half a meter in length with a bushy tail about 15 cm. long. It is pointed out that the low bady temperature of the tarbagan during hibernation enables the animal to survive and thus to carry over the infection from one season to the next, and the flea, *Oropsylla silantiewi* (Wagner), as well as perhaps other bloodsucking ectaparasites transmits the infection from animal to animal.

Camparable endemic foci of sylvatic plague occur in South Africa, where the gerbilles (Muridae, Gerbillinae) belonging to three genera, particularly *Tatera*, e g, *Tatera lobengulae* De Wint.; also the multimammate mause, *Mastomys coucha* (A. Smith) (Muridae, Murinae), and their flea parasites play the leading rôle.[16] In the Russian steppes the susliks, *Spermophilus rufuscens* and other species (Sciuridae) and their flea parasites, *Citellophilus tesquorum* (Wagner) and *Neopsylla setosa* Wagner, play a similar rôle. In North America, as already explained, ground squirrels (*Citellus* spp.) (Sciuridae) and their fleas, e g, *Diamanus montanus* (Baker) (*Ceratophyllus acutus* Baker), may be important reservoirs of sylvatic plague. In Sauth America, the cavy, *Cavia asperea* Pallas, and its fleas, e.g., *Rhopalopsyllus cavicola* (Weyenb.), play a similar rôle.

Sylvatic plague thus remains lacalized, and in each endemic region a particular native animal or group of animals (rodents) maintains the infection and when other small house-invading radents such as mice and rats come in contact with such a focus, the infection may be carried to human habitations, and human cases may result; or likewise if humans invade the territory of sylvatic plague, infection may also occur. Under such circumstances man occasionally contracts the infection by direct contact with infected rodents resulting in pneumonic involvement.

Wild rodent fleas.—Dunn and Parker [17] made an interesting study of the flea infestation of a variety of species of wild animals in the Bitter Root Valley of Montana. *Oropsylla* (=*Ceratophyllus*) *idahoensis* (Baker) was found infesting a large percentage of the 94 ground squirrels [*Citellus columbianus* (Ord)] examined, the average per animal being

3.86. While *O. idahoensis* (Baker) was by far the most common species of flea on this species of ground squirrel, six other species were taken in order of abundance, viz.: *Opisocrostis tuberculatus* (Baker), *Neopsylla inopina* Roth., *Monopsyllus eumolpi* (Roth.), *Cediopsylla inequalis* (Baker), and *Monopsyllus vison* (Baker) (one specimen). It is of interest to know that these authors took *Oropsylla idahoensis* (Baker) from the following species of wild animals: cottontail rabbits, *Sylvilagus n. nuttallii* (Bachman); snowshoe rabbits, *Lepus bairdi* Hayden; pine squirrels, *Sciurus hudsonicus richardsoni* Bachman; woodchucks, *Marmota f. flaviventer* (Aud. and Bach.); and the bushy-tailed woodrat, *Neotoma c. cinerea* (Ord). The woodchuck showed a heavy infestation (average 15.47 per animal) of *Thrassis acamantis* (Roth.). Observations made on the marmot in California also show a heavy flea infestation, averaging 26.57 fleas per animal according to unpublished data by Stewart.

Pearse [18] in his study of fleas on rodent hosts in Nigeria concludes that

"the ecological factors which are associated with a high degree of infestation are dry climate or habitat, the occupation of a more or less permanent home by the host, and large size of the host. Factors associated with low degree of infestation are wet climate or habitat, lack of permanent abode of host, small size of host, and wandering or arboreal habits of host."

While the California ground squirrels, *Citellus beecheyi beecheyi* (Richardson), have a number of species of fleas infesting them, among these *Diamanus montanus* (Baker), *Hoplopsyllus anomalus* Baker and *Malaraeus telchinum* (Roth.), there is usually a preponderance of the first-named species. Woodrats (*Neotoma*) commonly have several species, among them *Ctenopsyllus segnis* (Schön.), *Orchopeas sexdentatus sexdentatus* (Baker), *Anomiopsyllus nudatus* Baker, and *Malaraeus telchinum* (Roth.).

Infected and infective fleas.—In relation to the spread of sylvatic plague Meyer [19] calls attention to certain paradoxical observations, (1) that despite active reservoirs with hundreds of infected rodents very few cases of human plague were diagnosed on the North American continent; (2) that plague-infected fleas are taken from animals which had anatomically been declared as non-infected; (3) squirrel hunters and plague-survey crews are commonly covered by fleas and are bitten by squirrel fleas yet are not infected.

Meyer points out that in sylvatic plague man becomes infected with bubonic plague by immediate contact with the sick or dead rodents, flea transmission being infrequent. The danger represented by individual fleas appears therefore more limited than was originally believed. Wild

rodent fleas serve as "preservers" of plague infections in suitable rodent burrows for many months and under such natural conditions, while infected, harbor bacilli which are of low virulence or avirulent. These "preserver" fleas are believed to be "non-blocked."

Meyer continues,

"Rodents with latent infections will hibernate only to develop acute plague early in spring (March and April) Since the flea population is as a rule simultaneously very high, a great reservoir of infected vectors is thus created. The cadavers of the dead rodents are rapidly and effectively removed by the larvae of the *Lucilia* flies, while the fleas persist in the nests. With the migration of the young squirrels and chipmunks into the empty abandoned burrows and nests, highly susceptible hosts are thus brought in contact with infected and infective fleas. They may bring the vectors to the surface and some may thus contribute to the intensity and the expansion of the virus. These events are probably

[illegible]

cedures to reduce the rodent populations chemicals, preferably gases which are also insecticidal, must be chosen." (See methyl bromide fumigation)

Fleas and endemic typhus.—A mild form of typhus fever caused by Rickettsia prowazeki da Rocha-Lima exists in the South Atlantic and Gulf States of the United States. *Similarly* endemic typhus (tarbardillo) occurs in parts of Mexico, portions of South America, Europe, Asia and Africa. This infection has long been believed to be of murine origin and is referred to as "murine typhus."

Zinsser,[20] 1937, holds to the belief that both types may be either endemic or epidemic. He states: "Although the murine disease reaches man first from infected rats by flea vectors, this virus can also, like the European, pass from man to man by the louse . . . capable of epidemic dissemination of the murine as well as of the classical typhus. . . . Brill's disease is an imported classical typhus, endemically established in cities with large immigrant populations." Dyer and co-workers [21] reported in 1932 that "following the isolation of the virus of endemic typhus from rat fleas secured from a typhus focus in Baltimore, in November, 1930, investigations were inaugurated to determine the method by which the flea, *Xenopsylla cheopis* (Roth.), might transmit endemic typhus from rat to rat and from rat to man." It was found that *this species of flea was readily infected with the virus by allowing it* to feed on infected white rats. It was further found that the fleas were able to transmit the virus from rat to rat under conditions similar to those occurring in nature. Also the virus was transmitted to guinea pigs

by rubbing crushed infected fleas into wounds made by scratching, and the virus was present in the feces of fleas. Later Dyer et al. (U. S. Public Health Reports, April 22, 1932) reported the experimental transmission of the virus of endemic typhus from rat to rat by means of the rat flea, *Nosopsyllus* (=*Ceratophyllus*) *fasciatus* (Bosc). Laboratory-bred fleas (non-infected) were placed in a box with three freshly inoculated white rats. Fourteen days after the first and six days after the last rat had been introduced, five fleas were removed and emulsified in salt solution, then inoculated intraperitoneally into two guinea pigs. One of these animals developed typhus after an incubation period of ten days. The virus was recovered and studied in other experimental animals and was

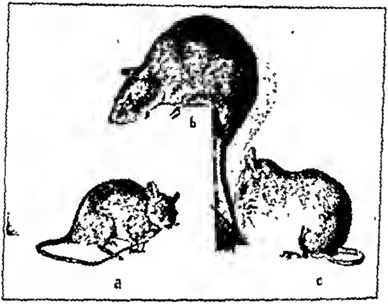

FIG. 145.—House rats (*a*) *Rattus r. rattus*, the black rat; (*b*) *Rattus n. norvegicus*, the brown rat, (*c*) *Rattus r. alexandrinus*, the roof rat × .13.

found to remain viable in the flea for at least 52 days, thus showing the importance of the flea as a reservoir under natural conditions.

Rats and rat control.—Together with the house mouse, *Mus musculus* Linn., the Old World rats belong to the family Muridae. *Rattus r. rattus* (Linn.) is the black rat; *Rattus rattus alexandrinus* (Geoffroy-Saint Hilaire and Audouin) is the roof rat or Alexandriae rat and lives in human dwellings, especially on upper floors; and *Rattus norvegicus norvegicus* (Erxleben) is the brown rat, the wharf or sewer rat, which inhabits drains, basements and burrows. (Fig. 145.) All species have become widely distributed through commerce and have succeeded in establishing themselves in many places because of their ability to adapt themselves to a wide variety of conditions; they are all omnivorous in food habits and are very prolific. With plentiful food and suitable nest-

ing and breeding places these rodents will readily become established in almost any part of the world, as they multiply enormously.

Rats breed from three to five times a year, each litter numbering from 6 to 19 young. After a gestation period of 21 days, the young are born in nests built in underground burrows or under floors, stacks of lumber, wood piles or other shelters. The young females reach sexual maturity in less than three months. Early spring and summer are the periods of greatest production, though young rats may be found during any month of the year.

Rats will eat grain and seed of practically any kind, flour and meal, cereal products, fruits and vegetables, bark of growing trees, bulbs, roots, eggs, chicks, ducklings, squabs, young rabbits, butter and cheese, fresh meat and carrion, fish, frogs, crustaceans, their own sick and dead.

Rat proofing, or "building out" the rat is by far the most important method of control. The initial cost may be greater, but in the long run it is the cheapest procedure against rats. Two general principles [22] should be kept in mind. "First, the exterior of those parts of the structure accessible, including porches or other appurtenances, must be constructed of materials resistant to the gnawing of rats, and all openings must be either permanently closed or protected with doors, gratings, or screens; second, the interior of the building must provide no dead spaces, such as double walls, spaces between ceilings and floors, staircases, and boxed-in piping, or any other places where rats might find safe harborage unless they are permanently sealed with impervious materials." The use of hard concrete in the construction of buildings, particularly farm buildings, is the best means of excluding rats. Wooden floors are a particular menace in basements and barns. Cement construction requires comparatively little skill and is relatively inexpensive.

Corncribs may be rat-proofed by entirely covering the walls and ceiling on the inside and the floors on the underside with wire mesh or hardware cloth. A heavy grade of woven wire, 12 or 15 gauge, is recommended.

Silver [23] points out that

> "to remove places where, without fear of molestation, rats make their homes and raise their families, is one of the most important problems in rat control. The surest way to permanent rat riddance is the removal of favorable rat harbors, for a rat will not remain where safe and comfortable shelter is not available."

Excellent designs for rat-proofing new buildings and corrective methods as applied to existing buildings are contained in Supplement No. 131 to the Public Health Reports.[24]

Cutting off the rat's food supply, i.e., to "starve out the rat," is an

important procedure in rat control. Where rats occur foodstuffs must be stored in rat-proof rooms or containers, covered garbage cans must be used, and other sanitary means of garbage disposal must be put into effect, such as incineration. Slaughter-house refuse, feed refuse about piggeries and poultry-houses must be properly dealt with. Cleanliness, neatness, good housekeeping in general and efficient farm management will aid materially in the control of rats and other rodents as well.

Destruction of rats may be accomplished by the use of *poisons* such as (1) *barium carbonate,* one part to eight parts of oatmeal mixed with water into a stiff dough and placed in rat runways, (2) red squill (sea onion), a powder made from the pear-shaped bulb of *Urginea maritima,* relatively harmless to human beings and domesticated animals (Silver, 1933, loc. cit.). The powder is mixed with a bait such as hamburger steak at the rate of one ounce to a pound of the meat, first mixing the powder with a little water to form a thin paste free from lumps. A variety of baits are recommended such as sausage, ground fresh fish, rolled oats, oatmeal, cornmeal, sliced fresh fruit, etc. The freshly prepared bait should be exposed late in the afternoon in order that it may be reasonably fresh when the rats commence feeding. Silver recommends that "every part of the premises where rats are likely to be present should be thoroughly treated, particularly those places in which rats have been accustomed to feed. A large number of small baits is more effective than a few large baits. Put out the bait in quarter-teaspoon pieces or in quantities about the size of the average marble. Place them consecutively, first a meat bait, then a fish bait, then a cereal bait, then meat, and so on. In poultry pens it is best to expose the baits in the feeding troughs while the chickens are shut up, or the baits may be exposed behind boxes or boards, so that chickens cannot reach them." If after the baits are left out for three days live rats are still observed at the end of a week, prebaiting with clean bait must be practiced in the identical way and placed where the poisoned baits were used. Prebaiting two or three times to overcome the suspicion of the rats is then followed with squill bait, and thus alternately until the rats have been destroyed.

Fumigation of rat burrows may be practiced when feasible, such fumigants as calcium cyanide, carbon bisulfide, exhaust gases from automobiles or other gasoline engines, and sulphur dioxide being used.

Trapping is best done by means of ordinary snap traps. The trigger must be large and at the same time sensitive. Baits such as meat, vegetables, or cereals should be fresh and are better used in alternation than one kind used continuously. Each time before using it is well to scald the trap and "sizzle" the meat bait (particularly bacon) when in place with a torch or match. Traps should be set in such a position in runways that the rat will pass directly over the trigger.

Ground squirrels.—The ground squirrels, also known as "digger" squirrels (family Sciuridae, *Citellus* spp.), commonly inhabit the open plains and grassy foothills, although their dwellings may be found on the rocky walls of canyons or in the more open portions of the yellow pine forests of the mountains. Some species inhabit high elevations in the Sierra Nevada Mountains. Their burrows are underground and are usually grouped in colonies varying in number from a few to hundreds. At the mouth of each burrow is a mound of earth and well beaten paths lead from burrow to burrow, radiating to various feeding grounds. Ground squirrels are active only during the daylight hours when they may be seen basking in the sun, scampering about in search of food, or standing motionless at the mouths of the burrows. Their food consists of acorns, fruits, seeds of various plants, and green herbage, according to the season and locality. Not all of the food is eaten as it is gathered. Much of it is tucked into ample cheek pouches and carried to the burrows, where it is stored away against an hour of need. A pair of ground squirrels raises but one family a year, breeding in the early spring. The young are usually born in March or early April; the number per litter averages about seven, though varying from four to fifteen.

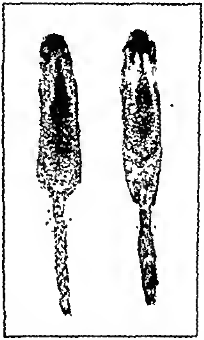

FIG. 146—Two species of the common "digger" ground squirrel of the Pacific coast. The squirrel at left is the Douglas ground squirrel, *Citel-*

In carrying on control operations one must bear in mind that there is a period of torpidity with low respiration in some of the ground squirrels which comprises an aestivation beginning in late summer and an hibernation through midwinter. Determined control during the spring and early summer is indicated.

Of the dozen species of digger squirrels within the State of California the following serve as examples: the dark colored, northern form (the Douglas ground squirrel) *Citellus b douglasii* (Richardson), ranges from San Francisco Bay northward; the brownish Beechey squirrel, *Citellus b. beecheyi* (Richardson), which lives in central California and the coast district south from the Golden Gate (Fig. 146); the gray-toned Fisher

ground squirrel, *Citellus beecheyi fisheri* (Merriam), whose habitat is in the southern San Joaquin and Owens valleys and throughout southern California; the Oregon ground squirrel, *Citellus oregonus* (Merriam), a short-tailed brownish gray squirrel of the northeastern part of California and Oregon, essentially an inhabitant of grasslands; the Belding ground squirrel, *Citellus beldingi* (Merriam), the picket-pin, also bob-tailed, of the high Sierra, from 6,500 ft. to about 12,000 ft.

Storer[25] states that the five most effective methods of destroying ground squirrels are: (1) poisoning with strychnine; (2) fumigation with carbon bisulfide; (3) trapping; (4) shooting; (5) encouragement of natural enemies.

Fumigation with carbon bisulfide.—Carbon bisulfide is an effective fumigant for ground squirrels and is commonly employed. The following account of this gas and its use is based largely on the work of Simpson.[26] Carbon bisulfide is obtained commercially in the form of a liquid, which is readily vaporized or is converted chemically into other gases. While it is the most useful material as applied against ground squirrels, there are some objectionable features, namely, it is very inflammable, must be kept in tightly closed containers, and, under certain conditions may explode; furthermore, during the dry season if "exploded" in the burrow there is danger of igniting dry grass or other inflammable material in the vicinity. If handled with as much care as gasoline, for example, the danger is not great. The advantages in its use are that it is readily converted into a poisonous gas, diffuses quickly, destroys life rapidly and can be used most readily during the rainy season when green food is abundant, which prevents the successful use of poisoned grain.

Carbon bisulfide may be used in one of two ways; namely, in the simple liquid condition by evaporation, when there will be but little waste, or it may be used by igniting or exploding it. In either case it is suggested that from one to three days prior to the application of the poison all squirrel burrows in the area to be treated should be stopped with earth. The holes found opened indicate the burrow in which there are squirrels.

The method of applying carbon bisulfide by the ignition method is as follows: to handle a large area to the best advantage two men should work together.

"One man is provided with a supply of 'waste,' 'sacking,' or other absorbent material, divided into a number of small balls about half the size of the fist. The bisulfide is carried in an ordinary one-gallon oil can and refilled from time to time from a supply kept in a cool place out of the sun He is supplied with matches. (Matches are dangerous, hence other methods of exploding the gas should be used.) His 'pardner' carries a mattock or long-handled shovel. On

arrival at an opened squirrel burrow, a ball of 'waste' is saturated with two ounces of bisulfide, dropped deeply in the burrow and then a match applied. After a moment's time the man with the shovel stops with earth this burrow and all other burrows near from which the gas escapes On subsequent inspection of the field all opened burrows will indicate holes lacking affective treatment."

Exploding the bisulfide thus causes considerable gas to escape, but

"the ignition produces a violent chemical reaction and as a result sufficient oxygen from the air combines with carbon and sulphur elements to produce a volume of gas three times that which the original bisulfide would produce on evaporation. The gases produced, carbon dioxide and other sulphur dioxide, in the proportion of one to two, seem just as effective as bisulfide of carbon, and the method is superior in that the explosion produced drives these gases deeply into the burrow."

Two ounces or 60 cc. of the bisulfide produce about 12 gallons of gas. To use the gas unexploded, simply omit igniting it.

A much cheaper and more efficient method of destruction with carbon bisulfide has been devised by Long[27] and others, namely, a pump with a device measuring the quantity of liquid, and serviceable at all seasons of the year. The pump loaded with nine pints of bisulfide weighs 25 pounds. Refined bisulfide should be used in this pump because the metal is rapidly corroded by the crude material. The refined bisulfide is said to contain 99.92 per cent carbon bisulfide and 0.08 per cent sulphur in solution and no hydrogen sulfide or sulphuric acid.

Only one-half ounce (15 cc.) is required for each hole, against two ounces by the ignition method, and it is claimed that the men using the pump have been able to treat from 200 to 250 holes with each gallon of the bisulfide, against 50 to 60 holes per gallon with the waste ball method above described.

The use of the apparatus is thus described (see Fig. 147): "Insert the hose in the squirrel hole at least one foot; then run one-half ounce of bisulfide from the reservoir into the measuring cup; then turn cock with handle down to allow liquid to run into vaporizing chamber, meanwhile covering the hole with dirt with the aid of a mattock. Then pump thirty strokes (in cold weather use one ounce with forty strokes). This equals 12 cubic feet or 1.5 per cent bisulfide gas. Withdraw the hose, close hole opening by stamping in the dirt with the heel and proceed to the next hole." Twenty minutes' to a half hour's treatment with air containing 2 per cent of carbon bisulfide is certain to be fatal. Improved carbon bisulfide pumps are on the market.

Fumigation with methyl bromide.—With the discovery that rodent fleas may serve not only as vectors of sylvatic plague but also as pseudoreservoirs, the necessity of flea control as well as rodent control is indi-

dissolving one heaping tablespoonful of dry [illegible] starch in a little cold water which is then added to three-fourths pint [illegible] stantly until a clear, thin paste is formed.) [illegible] *sirup and* one tablespoonful of glycerin and stir thoroughly. Add one-tenth ounce of saccharin and stir thoroughly. Pour this mixture over 16 quarts of clean barley and mix well *so that each grain is coated.*

Caution.—All containers of poison and all utensils used in the preparation of poisons should be kept *plainly labeled* as *POISON* and *out of reach* of children, irresponsible persons, and livestock.

According to Simpson (*loc. cit.*) grain poisoned with strychnine placed in proper containers will retain its poisonous character and remain effective for an indefinite period, but heavy dews and rain may remove the poison and destroy the effectiveness of the bait. Therefore, this method is applicable during the dry season only. The above author states that 30 kernels in the cheek pouches of squirrels rapidly prove effective, whereas 60 or 90 or more in the stomach may produce only a few convulsions and recovery ensues. He says, "This fact should be remembered in placing poison, for by scattering the grain a few kernels here and there near the burrow the squirrel is induced to store the grain temporarily in the cheek before a sufficient quantity is obtained for a meal. . . ." It should be scattered where the squirrel is accustomed to find food, and will probably be found most efficient if placed early in the morning, between the hours of three A.M. and seven A.M.

Trapping and shooting.—Where ground squirrels are digging into ditch banks, and in other cases where they must be disposed of promptly at any cost, special means must be adopted according to Storer (*loc. cit.*). Trapping and shooting are valuable under such circumstances. Both of these methods can be used at any season,

"but the time required to keep traps properly set, which is essential to success, and the high initial cost of traps as well as of ammunition make them too expensive for general use on large acreages. Trapping and shooting are also useful in cleaning up the few 'wise' squirrels that escape the poison and gas, and in reducing the breeding stock in the early spring before the annual increase

"The jump trap is the best, being lighter, easier to set, and having larger catching surface (pan or treadle) than the ordinary steel trap with an outside spring. The *jump trap* lies flat on the ground; the jaws have wide contact surfaces that reduce the chance of breaking the animal's leg; and the *inside* spring causes the trap to jump up and take a high grip on the leg instead *of on* the foot only. Such a trap may be set without bait in the *entrance to the* burrow, or may [illegible] *path or near* a feeding place. [illegible] *ion so that* the upper surface of the trap when set will be [illegible] *urrounding* [illegible] should be well secured. A long stake sharpened at one end, [illegible] the trap chain, *and then driven* well into [illegible] and also as a marker, *enabling* one readily to find the trap again.

Natural enemies.—Among the natural enemies of ground squirrels listed by Storer are coyotes, badgers, weasels, wildcats, red-tailed hawks, golden eagles, and gopher snakes Badgers, weasels, and snakes capture the ground squirrels in their burrows. Wildcats and coyotes lie in wait near the burrows until the squirrels venture forth in search of food. "Dixon examined 186 stomachs of wildcats from 40 different localities in California; 26 contained ground squirrels and these with other rodents were found to constitute more than half of the food. Hawks and eagles swoop down on the squirrels from the air. The importance of preserving as many as possible of these native enemies of the ground squirrels is evident." When poison is used in the control of ground squirrels, reasonable precaution should be exercised to prevent killing their natural enemies.

Rat fleas on ships and at seaports.—The United States Public Health Service has conducted a number of rat-flea and rat surveys at various seaports. Williams [30] reports that on a two-year survey of ships at the Port of New York 1,913 ships produced 18,265 rats, an average of 9.6 rats per ship The ship rat is almost exclusively the black rat, *Rattus r. rattus* (Linn.) and the roof rat, *Rattus rattus alexandrinus* (Geoffroy-St. Hilaire and Audouin), constituting 99 65 per cent of all rats. Because of the climbing habits of these rats, they are more likely to get into cargo and aboard ships than the Norway rat. The report indicates that the majority of ships carry few rats, and only about 50 per cent of arriving ships constitute about 90 per cent of the potential plague menace.

The dead rats collected after ship fumigations (hydrocyanic acid) were examined for fleas. A total of 7,886 fleas were taken from 18,265 rats, an average of 0.43 flea per rat, which was about 30 per cent of the expectation of fleas from live rats. Of the total number of fleas 6,992 (88 68 per cent) were *Xenopsylla cheopis* (Roth.) and 786 (9.97 per cent) *Nosopsyllus* (=*Ceratophyllus*) *fasciatus* (Bosc) The remaining number of rodent fleas were *Ctenopsyllus segnis* (Schön.), 63, *Xenopsylla brasiliensis* (Baker), four *Pulex irritans* Linn. appears as a single specimen and the cat and dog flea numbered but seven.

The rat-flea survey at Norfolk, Va (Hasseltine 1929),[31] resulted in the capture of 1,561 rats of which 883 harbored fleas; 4,898 fleas were taken Of these fleas 81.6 per cent were *Xenopsylla cheopis* (Roth.), and 17.7 per cent were *Nosopsyllus* (=*Ceratophyllus*) *fasciatus* (Bosc). The Norfolk survey was based on caged, trapped rats taken under favorable conditions for harborage and propagation. Consequently, the number of fleas per rat (the living rats were chloroformed) was much higher than the average per ship rat on fumigated vessels, i.e., 5.5 against 0.43; also *Rattus n norvegicus* (Erxleben) constituted all but four of the total number of rats taken at Norfolk.

The full grown larva, which is not unlike other flea larvae, is about 4 mm. in length, reaching this stage in about two weeks. The larva then spins a cocoon, pupates and in about two weeks (9 to 19 days) emerges as a fully developed flea. The life history requires from 30 to 60 days. Eggs are also deposited in the dust or dry droppings of poultry or in old nests, etc.

The fleas are most likely to attack the skin around the eyes, the wattles and comb and the anus or other bare spots. The ulceration and wart-like elevations around the eyes often become so aggravated that blindness results, the host is unable to find its food and death results.

To control the sticktight flea a thorough cleaning up is necessary. The debris, dust, etc., must either be burnt or treated liberally with kerosene right in the yard so that the fleas do *not* become distributed while the refuse is carried away. The yards and coops, particularly crevices, should be thoroughly treated with kerosene or a light fuel oil may be applied with a spray pump. The treatment must be repeated once every three or four weeks during the flea season. The use of sheep dips, carbolic acid sprays, etc., does not, as a rule, give good results in controlling chicken fleas.

In addition to the above treatment infested chickens must also receive attention in order to destroy the ovulating female fleas. This may be done by dipping the birds in a 2 per cent creolin solution. Since this flea also lives on dogs, cats, rats, quail, blackbirds and sparrows, suitable precautions should be taken to exclude these.

The western hen flea, *Ceratophyllus niger* Fox, is considerably larger than the sticktight and does not attach except when feeding and then only for a brief period. It readily attacks man and his cats and dogs It breeds primarily in fowl droppings. The European hen flea, *Ceratophyllus gallinae* Schrank, which has habits similar to *C. niger* Fox, is also at times a serious pest of poultry (Stewart 1927).[36]

Fleas in the household.—Very few species of fleas are annoying household pests Among these are particularly the dog and cat fleas, *Ctenocephalides canis* (Curt.) and *Ctenocephalides felis* (Bouché) (Fig. 149), and the so-called human flea, *Pulex irritans* Linn. While the common name might imply that there is a specific host relationship, this is not a fact, since interchange of host species is quite usual. Cat and dog fleas readily attack humans, and the human flea is often remarkably abundant on swine.

Fleas in the house generally indicate that cats or dogs or both are present or have been present fairly recently. Fleas may be carried on clothing into the house from pig pens. The exclusion of cats and dogs or their proper management is necessary to prevent and control flea

infestations. The exclusion of cats and dogs as well as rats from the basement or from beneath the house is an important measure.

Having been introduced into the house, fleas generally reproduce readily. Ordinarily fleas lay their eggs on the infested animal, but because the eggs are dry, they drop off when the host shakes itself. For this reason mats should be provided upon which the animals may sleep at night, and these should be shaken off every day or two over fire or into kerosene. The eggs are minute glistening white objects. The incubation period varies considerably, but they usually hatch in from five to six days, sometimes less, and the worm-like sparsely haired larvae emerge. The larvae feed on particles of dry blood, fecal matter, and various organic substances collected in corners and crevices. The larvae are quite active and in two to four weeks reach a length of about one-fourth inch, and then spin a crude cocoon in which they pupate. The flea

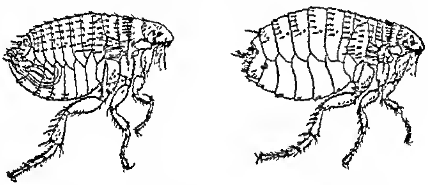

FIG 149.—*Ctenocephalides felis*, the cat flea; male (left); female (right). × 17.

emerges from the cocoon in about a week; thus three to four weeks is required for the entire life history of a common house flea.

Undisturbed mats, rags, and carpets favor the development of fleas. All carpets or matting tacked down and covering the floor should be dispensed with and smaller rugs substituted. In an infested house the bare floors can be easily mopped with a dry mop moistened with kerosene. All floors should be carefully treated in this manner. The treatment may need to be repeated in two or three weeks. Houses that have been vacant for several weeks may be badly infested with fleas because these insects are able to live without food for several weeks.

In cases of infested basements, outbuildings and the like, the bedding used by the animals should be burned and the floors cleaned of debris and this likewise burned, otherwise one simply distributes the pest. The floors may then be wet down with a five per cent cresol solution or sprayed with creosote oil. It is also possible to control an infestation of

fleas on a dirt floor by scattering a liberal quantity of coarse salt over the ground and then wetting it down.

If fleas develop in lawns, probably because of infested fertilizer, the grass may be sprayed with a nicotine sulphate solution, one part to 400 parts of water. The grass should be close-clipped to expose the larvae to the sun.

Swine pens should be provided with mechanical oilers supplied with crankcase oil or crude oil; the pens may also be oiled.

Dogs and cats can be kept well freed of fleas by dusting them every two weeks with derris powder or fresh pyrethrum powder. The animal should be placed on a sheet of paper while being dusted and the stupefied fleas which drop off or are combed off should be burned.

Dogs may be washed with a heavy lather of naphtha soap, wrapping the animal when well-lathered in a towel for 10 minutes, after which a thorough rinsing is given. Bathing in a 3 per cent cresol solution (*liquor cresolis compositus*)—four teaspoonfuls to a gallon of warm water is excellent. Cats should not be so treated.

Fleas as intermediate hosts of cestodes.—Although Melnikoff in 1867 showed that the biting louse of the dog, *Trichodecte canis* DeGeer, serves as an intermediate host of the double-pored dog tapeworm, *Dipylidium caninum* (Linn.); it has since been shown by other workers that fleas play a more important rôle in the transmission of this tapeworm, particularly the cat and the dog flea, *Ctenocephalides felis* (Bouché) and *Ct. canis* (Curt.). Although *Dipylidium caninum* (Linn.) is a tapeworm of dogs, cats and certain wild carnivores, it also occurs in man, particularly young children. The tapeworm measures from 20 to 70 cm. in length; the mature proglottids are shaped like pumpkin seeds, and each has a double set of reproductive organs with a genital pore on each side. The scolex has a rostellum which is armed with three to seven circlets of spines and has four deeply cupped oral suckers. The embryonated eggs of the tapeworm are discharged in the fecal material of the host and are ingested by the larval flea and develop into cysticercoids in the body cavity of the insect. Thus the mature flea is infected and when ingested by a cat or dog or human, the cysticercoids are liberated and develop into tapeworms in the animal's digestive tract.

A common tapeworm of rats and mice, rarely man, *Hymenolepis diminuta* (Rudolphi), has numerous intermediate arthropod hosts, among them *Nosopsyllus fasciatus* (Bosc) and *Xenopsylla cheopis* (Roth.).

The Commoner Species of Fleas

Systematic.—There are more than 800 described species of Siphonaptera divided into six families, (1) Hectopsyllidae, (2) Pulicidae, (3)

Dolichopsyllidae, (4) Ischnopsyllidae, (5) Hystrichopsyllidae, (6) Macropsyllidae. (See Fig. 141.)

Key to the Families of Siphonaptera

(Modified by Stewart after Ewing)[31]

1. The three thoracic tergites together longer than the first abdominal tergite 2
   The three thoracic tergites together shorter than the first abdominal tergite Hectopsyllidae
2. No vertical suture from dorsal margin of head to bases of antennae; frontal region almost evenly rounded along margin.................. 3
   A vertical suture passing upward from the bases of the antennae to the dorsal margin of head; margin of frontal region usually most strongly curved at vertex 4
3. Abdominal tergites with but a single row of setae.............Pulicidae
   Abdominal tergites with at least two rows of setae......Dolichopsyllidae
4. *Head without a pair of dark antero-ventral flaps on each side..........* 5
   Head with a pair of dark antero-ventral flaps on each side . Ischnopsyllidae
5. Occipital region without dorsal incrassation; frontal region entire Hystrichopsyllidae
   Occipital region with dorsal incrassation; frontal region divided, the anterior part bearing a border of spines................Macropsyllidae

Family Pulicidae

Pulex irritans Linn. (Fig. 150) is commonly known as the human flea. It is cosmopolitan in distribution and occurs on many domesticated animals, particularly swine. This species has neither oral nor pronotal

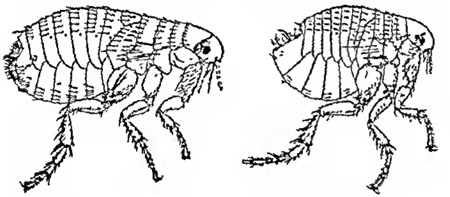

FIG. 150.—*Pulex irritans*, the human flea; male (right); female (left). × 17.

ctenidia. The metacoxae have a row or patch of short spinelets on the inner side; the mesosternite has an internal rod-like incrassation extending dorsoanteriorly. The mandibles extend about halfway down on the fore coxae which distinguishes this species from *Pulex dugesii* Baker

(mandibles extending at least three-fourths the length of the fore coxae) also known as a human flea but restricted to Mexico and the border states of the United States. *Pulex irritans* Linn. transmits plague under laboratory conditions and may be the chief vector of two unusual types of plague, e.g., *viruola pestosa* (a vesicular form) and *angina pestosa* (a tonsillar form) found in Ecuador.

Ctenocephalides canis (Curtis) and *Ctenocephalides felis* (Bouché) are the dog flea and cat flea respectively. Both species attack cats and dogs as well as man. Both have the oral ctenidia consisting of eight spines and the pronotal comb of 16 spines. They may be seperated as follows:

In the female the head is fully twice as long as high (seen from side); two or three bristles on metathoracic episternum; bristles on metathoracic epimeron, first row, four to eight, second row, five to seven; seveo to ten bristles on inner side of hind femur. . . . . *felis*

In the female the head is less than twice as long as high (seen from the side); three or four bristles on metathoracic episternum; bristles on metathoracic epimeron, first row, seven to eleven, second row, seven to nine; ten to thirteen bristles on inner side of hind femur. . . . . *canis*

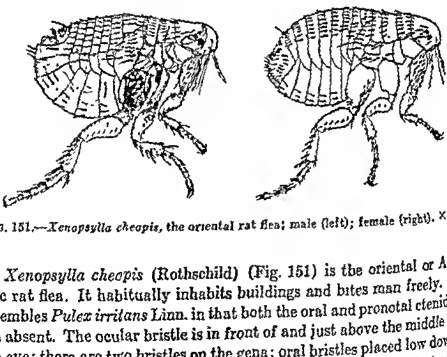

FIG. 151.—*Xenopsylla cheopis*, the oriental rat flea; male (left); female (right). × 17.

Xenopsylla cheopis (Rothschild) (Fig. 151) is the oriental or Asiatic rat flea. It habitually inhabits buildings and bites man freely. It resembles *Pulex irritans* Linn. in that both the oral and pronotal ctenidia are absent. The ocular bristle is in front of and just above the middle of the eye; there are two bristles on the gena; oral bristles placed low down just above the base of the maxillae; each abdominal tergite has but one row of bristles; the hind femur has a row of about eight bristles. The mandibles reach nearly to the end of the anterior coxae. Incrassation of mesosternite consists of one rod extending anterodorsally aod one rod extending upward nearly perpendicularly. (See Fig. 141.)

Mellanby [38] (1933) has performed experiments proving that *X. cheopis* (Roth) can complete its life history between 18° C. and 35° C. in moist air. Between 18° C. and 29° C. air with a relative humidity of 40 per cent is unfavorable, while with 60 per cent pupation takes place successfully. Pupation at 18° C. required eight days, at 22° C. it required six days and at 29° C. to 35° C. it required four days. The developmental zero for pupation is about 15° C.

Xenopsylla brasiliensis (Baker) is an African species, the predominant rat flea in Uganda, Kenya and Nigeria. It has spread to South America and certain areas in India. It is regarded as a more important vector of plague than *X. cheopis* (Roth.) in Kenya and Uganda, since it is "the flea of the hut" while the latter infests rats of stone and brick buildings.

Xenopsylla astia Roth. has a restricted distribution

"being found mostly along the low-lying coast of Ceylon, the east coast of India and along the opposite coast of Bengal . . . while *X astia* may be the responsible vector (of plague) in certain circumscribed and isolated outbreaks, the available evidence . . points to its inferior position in the epidemiological picture. . . . Moreover *astia* outbreaks, if and when they do occur, are not known to carry over from one season to another" (Wu, loc cit)

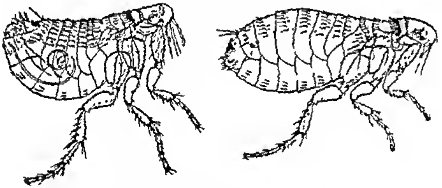

Fig 152 —*Nosopsyllus fasciatus*, the rat flea, male (left), female (right) × 17

Xenopsylla hawaiiensis Jordan is a common flea of the Hawaiian rat, *Rattus hawaiiensis* According to Eskey reported by Jordan [39] this species of flea has a very peculiar distribution.

"It has not been found in Honolulu or vicinity, while it is quite common on rats caught about nine miles away on the opposite side of the island It is essentially a flea of field rats and rarely found on rats caught in buildings."

Family Dolichopsyllidae

Nosopsyllus (=*Ceratophyllus*) *fasciatus* (Bosc) is the European rat flea. (Fig 152.) It is widespread over Europe and America, being less

common in other parts of the world. It has been recorded on rats, house mice, pocket gophers, skunk, man and many other host animals. It has but one ctenidium, the pronotal, which has 18 or 20 spines; there are three bristles in front of the eye, and in the female two, and in the male four in front of these; there are three or four hairs on the inner surface of the hind femur. *N. fasciatus* (Bosc) is regarded as a negligible factor in the causation of natural outbreaks of plague.

The genus *Nosopsyllus* may be distinguished from the genus *Diamanus* by the fact that in *Diamanus* there are long, thin bristles on the inside of the mid and hind coxae from the base to the apex, while in *Nosopsyllus* such bristles occur at most in the apical half.

Diamanus montanus (Baker) (*Ceratophyllus acutus* Baker) (Fig. 153) is a common species of squirrel flea described from California. This species may be recognized by a spine at the tip of the second joint of

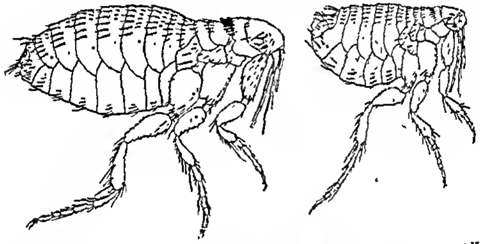

FIG. 153.—*Diamanus montanus*, the squirrel flea; male (right); female (left). × 17

the hind tarsus longer than the third joint and reaching over on to the fourth joint; the abdominal tergites have each two rows of bristles; the male claspers are very large and long, and sickle-shaped.

Ceratophyllus niger Fox was originally described from specimens taken from man and from *Rattus n. norvegicus* in California.

Ceratophyllus gallinae Schrank is commonly known as the European hen flea although it has a wide range of hosts. See previous pages.

Family Hectopsyllidae

Tunga penetrans (Linn.) [*Dermatophilus* (=*Sarcopsylla*) *penetrans* (Linn.)] is commonly known as the chigoe flea. See previous pages.

Echidnophaga gallinacea (Westw.) is commonly known as the sticktight flea of poultry and other animals. See previous pages.

Family Hystrichopsyllidae

Ctenopsyllus segnis (Schön.) (*Leptopsylla musculi* Duges) is the cosmopolitan mouse flea (Fig. 154). It is commonly found on rats. It bites

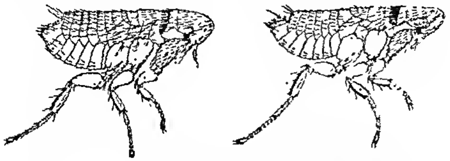

Fig. 154.—Ctenopsyllus segnis, a mouse flea; male (right), female (left). × 17.

man reluctantly and is regarded as a weak vector of plague; its rôle in human outbreaks is considered negligible.

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CHAPTER XXI

TICKS AND TICK-BORNE DISEASES

Class Arachnida, Order Acarina, Superfamily Ixodoidea

Introduction.—Probably all species of vertebrate animals are subject to attack by ticks, but particularly mammals, whose warm blood is highly attractive to these parasites. The food of ticks consists entirely of blood and lymph and both males and females are bloodsuckers, as are all stages. Hunters have long observed tremendous infestations on the bodies of wild animals. Stockmen suffer enormous losses due to the attack of ticks on cattle, horses, and other stock. Hunter and Hooker,[1] United States Bureau of Entomology, reported that as many as two hundred pounds of blood may be withdrawn from the host by ticks in a single season. Woodward and Turner,[2] using the common cattle tick, *Boöphilus annulatus* (Say), found that tick-infested cows under experimental conditions gave only 65.8 per cent as much milk as tick-free cows. Furthermore, the tick-free cows gained 6.1 per cent in body weight during the time of the experiment, while the tick-infested gained 3.6 per cent. Death from loss of blood (exsanguination) by ticks is believed to be possible. Jellison and Kohls [3] have conducted experiments with *Dermacentor andersoni* Stiles and conclude that "tick-host anemia is not only an experimental disease but occurs with some frequency in nature, and may be the immediate cause of death in animals."

During the months of October to March, 1935–36, one riding academy in Alameda County, California, lost eighty-three horses from loss of blood (exsanguination) by *Dermacentor olbipictus* (Packard). Autopsies, blood examinations and blood inoculation into other horses produced no symptoms not attributable to simple secondary anemia. Some species of ticks are highly venomous and others may cause paralysis in both man and domesticated animals.

While the natives of East Africa, the upper Congo and other endemic areas of Africa long associated ticks with their recurrent fever, little attention was given to these organisms as vectors of disease until the epoch-making discoveries of Smith and Kilbourne (loc. cit.) in 1889–1890 proving tick transmission of Texas cattle fever. In 1905 Dutton and Todd (loc. cit.) showed that African relapsing fever is tick-borne and in 1906 Ricketts (loc. cit.) proved tick transmission of Rocky Mountain spotted fever. Tick transmission of tularaemia was reported in 1924

by Parker, Spencer and Francis (loc. cit.) In addition to these diseases bovine anaplasmosis, biliary fever of dogs, fowl spirochaetosis and various other infections of domesticated animals and man are wholly or in part transmitted by ticks. Thus ticks participate in the transmission of pathogenic spirochaetes, piroplasms, anaplasms, rickettsias and bacteria and in most instances the relation between the vector and the causal agent is obligatory.

There are about three hundred known species of ticks of which forty occur in the United States.

Characteristics of ticks.—With the few wingless forms well in mind such as the sac-like Pupipara, particularly the sheep ked, ticks are easily distinguished from the insects, in that the body is not divided, i e., there is a strong fusion of the thorax and abdomen producing a sac-like leathery appearance. The head as in insects is lacking, but the mouth parts together with the *basis capituli* in many species (Ixodidae) form a structure known as the capitulum. The mouth parts (Fig. 155) possess a structure known as the hypostome which bears minute recurved denticles. Like other Arachnida the mature ticks bear four pairs of legs; the larvae are hexapod.

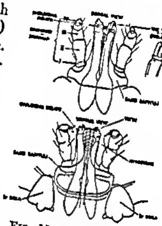

Fig. 155.—Showing mouth parts of a tick. (After various authors)

All ticks bear a pair of spiracles, situated latero-ventrally on the abdomen, one on each side near the third and fourth coxae. A pair of simple eyes may be present. Many species of ticks are eyeless.

Ticks vary considerably in size according to species but rarely exceed 15 mm. in the fully engorged females. The females are capable of great distention, and when fully engorged are seed-like in form.

Tick mouth parts and feeding habits.—The capitulum or head bears the mouth parts and accessory external structures. (Fig. 155.) The basal portion is known as the *basis capituli*, from which projects forward and dorsally a pair of protrusible *chelicerae*. The distal portions (*digits*) of the chelicerae are divergent and provided with recurved teeth. Projecting forward and situated ventrally and medianly on the *basis capituli* is the *hypostome* bearing many recurved teeth. Laterally are located the *palpi* (one pair), consisting of four articles, of which two or more may be used —commonly three are visible.

When sucking blood both the hypostome and the chelicerae are inserted into the skin of the host. The impression that the mouth parts are formed like a corkscrew and may be removed by "unscrewing" is, of

course, erroneous. By "unscrewing" one is more likely to leave the mouth parts in the flesh. Because of the recurved teeth the tick is enabled to hold so fast to the host that it is difficult to remove it without tearing the capitulum from the body of the tick. The tick itself, however, withdraws its mouth parts quickly and apparently with little effort by slipping the hoodlike portions of the capitulum over the relaxed mouth parts and with a quick jerk dropping off and escaping.

One does not usually feel the tick when it is biting. As Cooley[4] has so well said, "a person is always completely surprised when he finds a tick attached." The best way to remove a tick, and this should be done without delay, is to take hold of it with the fingers and pull it off slowly with a firm straight pull without jerking.

The length of time that a tick remains attached in the act of uninterrupted feeding depends on the species and the stage of development. The seed ticks commonly feed for a number of days; the nymphs and adults differ greatly in this respect—thus the common poultry tick, *Argas persicus* (Oken) feeds nightly and intermittently, while the nymphs and adults of the southern cattle tick, *Boöphilus annulatus* (Say) feed from six to eight days before becoming fully engorged. Other species of ticks, notably the California relapsing fever tick, *Ornithodoros hermsi* Wheeler, is able to engorge fully in from 15 to 20 minutes. Both male and female ticks suck blood; however, only the females become greatly distended when engorged in the case of the Ixodidae, while both sexes become distended in the Argasidae.

Life history.—Under natural conditions a few species of ticks show a marked host specificity, e.g., *Boöphilus annulatus* (Say), the southern cattle tick, and *D. parumapertus* Neum. on jackrabbits. However, most species have a fairly wide range of hosts, e.g., *Dermacentor occidentalis* Neum. The life histories of ticks vary considerably for the several species, hence it is quite impossible to generalize, except that it may be said that all species of ticks pass through four stages (*egg, seed tick, nymph* and *adult*) in from six weeks to two years, e.g., the Rocky Mountain spotted fever tick, *Dermacentor andersoni* Stiles, requires normally about two years to complete its life history. The fully engorged females usually deposit their eggs on the ground, the number varying from 100 in some species to 5,000 and over in others. The newly hatched larvae, known as seed ticks, are hexapod (six-legged) and remain in this condition until the first molt is completed. The nymph emerges from the first molt with its fourth pair of legs present, and remains in this stage until the second molt, after which the adult tick emerges; often a third or fourth molt or more (Argasine ticks) takes place before the adult stage is reached. As many as seven molts may occur in certain Argasine ticks. Copulation takes place after the last molt, when the females engorge and

then deposit eggs. In the majority of species the ticks drop off the host animal to molt, but in several species, notably the Texas cattle fever tick *Boöphilus annulatus* (Say), the molting takes place on the host. There may be two or possibly three generations of ticks in one year under very favorable climatic conditions in species which molt on the host.

The seed ticks emerging from the eggs on the ground commonly climb up grasses and other low vegetation in order to come within easy reach of grazing or passing animals. The nymphs and adults employ the same method. Wild lilac (*Ceanothus*) is a favorable shrub for the purpose, in fact in some localities in California it is known as a "tick bush"

The larvae having reached the body of a host, there follows a sequence of feeding and molting until maturity is reached When this sequence is completed on one animal, for example the cattle fever tick, *Boöphilus annulatus* (Say), the species is said to be a one-host tick. When this sequence is completed on two host animals, as with the African red tick, *Rhipicephalus evertsi* Neum, the species is said to be a two-host tick. The larvae of this two-host species hatch on the ground like other ticks, then proceed to attach themselves to the ears (often inside) and flanks of cattle, where they become fully engorged and molt while on the host The nymphs then engorge and drop off to molt, after which the adult tick emerges and must now find a second host upon which it engorges itself and then drops to the ground where the females lay eggs

When the tick species requires three different hosts to complete its cycle, it is called a three-host tick, as for example, *Dermacentor andersoni* Stiles, the Rocky Mountain spotted fever tick. In this species the larvae select smaller animals such as ground squirrels upon which engorgement is achieved after which the larvae drop to the ground to molt and reach the nymphal stage In this stage the second host is usually a larger animal such as a rabbit or coyote. After engorgement on this host the nymph drops to the ground and with its last molt (the third) it reaches the adult stage and once more finds a host animal (the third host) upon which it feeds and thereafter drops to the ground where the females lay their eggs.

In such species of ticks as *Ornithodoros hermsi* Wheeler, the vector of relapsing fever in California, several individual host animals are required and consequently such species are known as many-host ticks There are usually five molts in this species each of which is completed off the host, hence at least five host animals are needed to complete the cycle.

Longevity.—The longevity and hardiness of ticks is something truly remarkable, a matter not to be overlooked in control measures, particularly pasture rotation in which starvation is the principal factor. Furthermore, chemicals which destroy the life of most insects in a few minutes

act very slowly on these arachnids. The writer has found the poultry tick *Argas persicus* (Oken) to be particularly resistant.

Unfed larval ticks of the above species remain alive quite readily for a month and would probably survive longer if kept in a moist chamber. Nymphs survive a longer time and the adults even longer than the nymphs. Nuttall and Warburton [5] cite cases in which nymphs of this species survived two months, and adults (unfed) "a little over two years." Graybill [6] reports considerable variation in the longevity of the Texas fever tick, depending on the season of the year; unfed larvae survived from 7 to 85 days (average 38.6) for July, and 30 to 234 days (average 167.4) for October. Nuttall and Warburton (loc. cit.) cite cases in which the larvae of *Ixodes ricinus* (Linn.) survived 19 months, unfed nymphs 18 months and unfed adults 15 to 27 months. Unfed adult *Dermacentor andersoni* Stiles survived 413 days. The author had a female *Ornithodoros megnini* Dugès remain alive without food in a pill box for two years and seven months. A specimen of *O. coriaceus* Koch remained alive over six years with an average of two blood meals annually.

Classification.—Although the classification of ticks, according to Nuttall and Warburton (loc. cit.), may be considered as dating from Linnaeus (1746), who included them under Acari in the genus *Acarus*, scientific nomenclature did not actually commence until the time of Latreille (1795). Latreille called the acari "tiques" and divided them into eleven genera two of which were *Argas* and *Ixodes*. (Fig. 156) There are now a dozen well-recognized genera.

Ticks were ranked in a special order, Ricini, by C. L. Koch in 1844. Neumann in 1901 in agreement with most zoölogists of that time regarded the Ixodidae as merely a family of the order Acarina and grouped the genera into two subfamilies, (1) the Ixodinae and (2) the Argasinae. Banks in 1894 raised the ticks to the rank of a superfamily Ixodoidea. Acari of the suborder Metastigmata have breathing pores somewhat posteriorly situated; possessing a movable false head, a capitulum consisting of a basal portion, *basis capituli*, a pair of palps, protrusible chelicerae with digits serrate externally and a rigid hypostome almost always toothed on its ventral surface. The superfamily Ixodoidea is divided into two families, namely: (1) Ixodidae, which comprises scutate ticks with a terminal capitulum; sexual dimorphism is marked; the males have a scutum which almost entirely covers the dorsum and are incapable of great distention; in the females the scutum is a small shield immediately behind the capitulum; the females are capable of enormous distention. (2) Argasidae, which includes ticks without a scutum; sexual dimorphism not marked; capitulum ventral and papli leg-like; the eyes when present lateral and situated on the supracoxal folds; the spiracles very small.

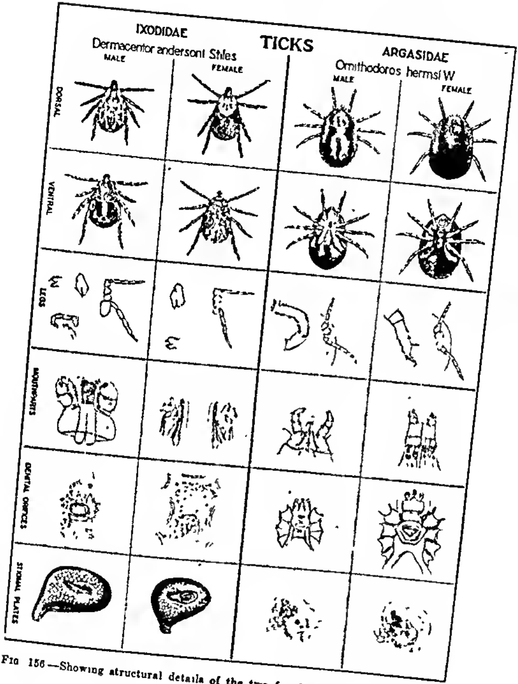

FIG 156—Showing structural details of the two families of ticks, Ixodidae and Argasidae

The two families may be readily separated by means of the following table (Table XVI), and Figure 156.

TABLE XVI

DIFFERENCES BY WHICH THE TWO FAMILIES OF THE IXODOIDEA MAY BE SEPARATED. (ADAPTED AFTER NUTTALL.)

	Argasidae	Ixodidae
Sexual dimorphism	Slight	Marked
Capitulum	Ventral	Anterior
Base	No porose areas	Porose areas in—
Palpi	Leg-like, with subequal articles	Relatively rigid, of very varied form
Body		
Scutum	Absent	Present
Festoons	Absent	Generally present
Eyes (when present)	Lateral on supracoxal folds	Dorsal on the sides of the scutum
Legs		
Coxae	Unarmed	Generally armed with spurs
Tarsi	Without ventral spurs	Generally armed with 1 or 2 ventral spurs
Pulvilli	Absent or rudimentary	Always present

FAMILY IXODIDAE

Nuttall and Warburton (1911, loc. cit.) include nine genera in the family Ixodidae, namely: *Ixodes, Haemaphysalis, Dermacentor, Rhipicentor, Rhipicephalus, Margaropus, Boöphilus, Hyalomma* and *Amblyomma*, arranged as follows:

- Ixodidae
  - Prostriata
    - 1 Ixodes
  - Metastriata
    - Brevirostrata
      - Group 1
        - 2 Haemaphysalis
      - Group 2
        - 3 Dermacentor
        - 4 Rhipicentor
        - 5 Rhipicephalus
        - 6 Margaropus
        - 7 Boophilus
    - Longirostrata
      - Group 1
        - 8 Hyalomma
      - Group 2
        - 9 Amblyomma

Genus Ixodes.—This genus, which comprises over *fifty species*, is clearly separated from all other genera of the family Ixodidae by the

anal groove surrounding the anus in front (Prostriata) and the absence of festoons. The remaining genera fall naturally into two divisions (see diagram), the one characterized by a comparatively short capitulum, and the other by a comparatively long one. Eyes are absent; spiracles are round or oval; palpi and *basis capituli* of variable form; coxae either unarmed, trenchant, spurred or bifid; tarsi without spurs; sexual dimorphism pronounced, especially with regard to the capitulum; in the male the venter is covered by non-salient plates; one pregenital, one median, one anal, two adanal and two epimeral plates; e g., *Ixodes ricinus* (Linn.), commonly known as the European castorbean tick. It is very widely distributed and feeds on a wide variety of hosts. It has several varieties, among them *Ixodes ricinus* var. *californicus* Banks (Fig. 157), which is a common deer tick in California but flourishes on cattle as well. It bites human beings freely and often causes severe disturbances. *Ixodes hexagonus* Leach occurs on squirrels in California.

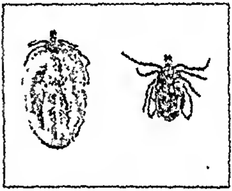

FIG 157—A common deer and cattle tick of California, *Ixodes ricinus* var. *californicus*, female (left), male (right) × 3 5.

Genus Haemaphysalis.—The members of this genus, numbering about 45 species, are usually small and but slightly chitinized, and the sexes are very similar They are inornate and eyeless, but have festoons; the second segment of the usually short conical palpi projects laterally beyond the *basis capituli*, forming an acute angle. The spiracles of the males are ovoid or comma-shaped; in the female rounded or ovoid The genus is commonly found on mammals but only occasionally on birds.

Haemaphysalis leporis-palustris (Packard) is a widely distributed North and Central American species. Although it is commonly known as the rabbit tick, it has been taken on a number of species of birds and occasionally on domestic animals such as the horse, cat and dog. It rarely bites man but is important in the spread of Rocky Mountain spotted fever and tularaemia

on cattle. This tick

Genus Dermacentor.—Usually ornate ticks with eyes and festoons; palpi short, broad or moderate; *basis capituli* rectangular dorsally. In

some species coxae I to IV of the male increase progressively in size; in all species coxa IV is much the largest; the male shows no ventral plates or shields. Coxa I is bifid in both sexes. The spiracles are suboval or comma-shaped. The genus includes about 15 species.

Dermacentor variabilis (Say) is the one principal, if not the only, vector of Rocky Mountain spotted fever in the central and eastern portions of the United States. It is alsn an important carrier of tularaemia and bovine anaplasmosis. It may cause canine paralysis and is a first-class pest of dogs, which are the preferred host. It also freely attacks horses and many other animals, including man. The immature stages feed almost exclusively on small rodents such as mice.[7] It is a widely distributed North American species. It is reported to be most abundant along the Atlantic coast.

The fully engorged females drop from the host and in four to ten days lay eggs on the ground. The incubation period during the summer months is about thirty days. The larvae remain in clumps on the soil or on low-growing vegetation while awaiting a host, usually a mouse. The period of larval engorgement varies from 3 to 12 days, after which the larvae drop to the ground and molt in about a week. The nymphs, having reached a host, again usually a species of mouse, engorge in from 3 to 10 days, and once more drop to the ground and molt in from three weeks to several months. The unengorged adults may live for more than two years; however, having reached the adult stage the ticks attack dogs and other large host animals. Engorgement of the females requires from 5 to 13 days Mating takes place on the host. Like the unengorged adults the immature stages have a remarkable longevity in the absence of suitable hosts, which may prolong its life history two or more years although under favorable conditions the life cycle from egg to adult may not require more than three months.

Dermacentor albipictus (Packard) is commonly known as the winter tick, elk tick or horse tick. It is a widely distributed North American species. It is a one-host tick, and does not occur on the hosts during the summer months; it is distinctly a winter tick. The eggs are laid during the spring months and hatch in from three to six weeks. The seed ticks then bunch tightly together, remaining in a torpid condition until the first cold weather in autumn, when they become very active and seek host animals. Molting takes place on the original host animal. The females reach maturity with the final molt and engorgement usually in about six weeks after the seed ticks have become attached. Although the females drop off the host after final engorgement as do other ticks, egg-laying is delayed until spring, often after an interval of several months.

Hearle (1938, loc. cit., p. 375) states that heavy infestations of horses, cattle, moose, elk and deer may result in death from "tick poverty" due

to the drain on the vitality of the infested hosts. In this respect, Hearle states, it is the most important species occurring in Canada. This tick, it is reported, caused a loss of at least 20 per cent of the moose population in Nova Scotia. A new disease of moose (*Alces americana americana* Jardine) is described by Thomas and Cahn [8] as occurring in northeastern Minnesota and the adjacent region. It is reported that guinea pigs and rabbits infested with the tick, *Dermacentor albipictus* (Packard), from diseased moose have reproduced in detail the symptoms of weakness, anemia, paralysis, excessive blind activity and death as exhibited by infected moose. The causative bacterium is described as *Klebsiella paralytica* "because of the paralysis it causes." (Cahn, Wallace and Thomas.[9])

Genus Rhipicentor.—This small and relatively unimportant genus of ticks is inornate, eyes and festoons present; palpi short with *basis capituli* hexagonal dorsally and having very prominent lateral angles. Coxa I is bifid in both sexes; coxa IV is much the largest; no ventral plates or shields; spiracles subtriangular in the female or comma-shaped in the male. The genus is represented by *Rhipicentor bicornis* Nuttall and Warburton.

Genus Rhipicephalus.—This genus comprises about thirty species. They are usually inornate, possess eyes and festoons; the palpi are short and the *basis capituli* is usually hexagonal dorsally. Coxa I is bifid. The male possesses a pair of adanal shields and usually a pair of accessory glands; some males when replete show a caudal protrusion. The spiracles are bluntly or elongatedly comma-shaped.

Rhipicephalus sanguineus (Latr.) is commonly known as the brown dog tick; its principal host is undoubtedly the dog, although it is known to attack numerous other animals. It is a widely distributed tick occurring principally in tropical and subtropical climates, and is widely known as a vector of malignant jaundice of dogs. The adult ticks are most often found in the ears and between the toes of dogs, and the larvae and nymphs in the long hair at the back of the neck. McIntosh [10] states that the eggs are deposited in cracks and crevices of the kennel or other quarters frequented by the dog. The eggs hatch in from 20 to 30 days and over, depending upon temperature. The life cycle corresponds to that of other species of Ixodine three-host ticks.

Genus Margaropus.—This genus has an obsolete anal groove, no ornamentations or festoons; the palpi are short and the capitulum is highly chitinized and similar in shape to that of *Boöphilus*. The coxae are conical and unarmed excepting for a small spine posteriorly on coxa I. The male has a median plate prolonged into two long spines projecting beyond the anus on both sides; when replete it shows a caudal protrusion. It may be separated from *Boöphilus* which it closely resembles by the

presence of greatly thickened posterior legs and by the prolonged median plate.

Margaropus winthemi Korsch, the Argentine tick, a native of South America which has been introduced into South Africa, is frequently found on horses and occasionally on cattle. When engorged the females may easily be mistaken for *B. decoloratus* (Koch) but may be distinguished by the dark bands at the joints of the legs. This is a one-host tick, usually present in larger numbers during the winter.

Genus Boöphilus.—Members of this genus have neither festoons nor ornamentations but eyes are present. The palpi and hypostome are short, compressed and dorsally and laterally ridged. The *basis capituli* is hexagonal dorsally and slightly chitinized. Coxa I is bifid; the anal groove is obsolete in the female and faintly indicated in the male. Unfed adults are small, the scutum of the female quite small and the spiracles circular or oval in both sexes. There are less than half a dozen species.

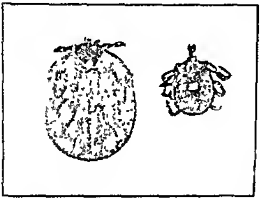

FIG. 158.—The lone star tick, *Amblyomma americanum*. × 3.5

Boöphilus annulatus (Say) is fully discussed later in this chapter.

Genus Hyalomma.—The ornamentations are absent or present and may be at times confined to the legs; with eyes, with or without festoons, with long palpi and *basis capituli* subtriangular dorsally. The female approaches *Amblyomma*. The male with a pair of adanal shields, and with or without accessory adanal shields and two posterior abdominal protrusions capped by chitinized points. Coxa I bifid. Spiracles comma-shaped. The genus includes less than half a dozen species.

Hyalomma aegyptium (Linn.).—The "bont-leg" tick, with its two varieties, is fairly widespread over much of southern Europe, Asia and Africa. The adults are parasitic on cattle, horses, sheep, goats, wild mammals and occasionally birds, while the larvae and nymphs are found on rodents, hares and birds, frequently infesting domestic poultry. It is usually a two-hosted tick, the larvae and nymphs feeding on the same host, though the larvae may drop off and seek a new host.

This tick is very hardy and exists under extremes of heat and cold. The adults attach by preference around the anus and genitalia and may produce severe lesions Lameness is frequently encountered in sheep because of tick bite.

Genus Amblyomma.—Generally ornate ticks with eyes and with festoons. With long palpi, of which article 2 is especially long; *basis*

capituli of variable form. The male without adanal shields, but small ventral plaques are occasionally present close to the festoons. Spiracles subtriangular or comma-shaped. There are about 90 species in this genus. Among the species of this genus are *Amblyomma americanum* (Linn.) the "lone star" tick (Fig. 158) of the southern United States, particularly Texas and Louisiana. This species has a wide range of hosts, including wild and domestic animals as well as man. It takes high rank as a pest.

The Rocky Mountain wood tick, Dermacentor andersoni Stiles (Fig. 159), is a widely distributed and very common species throughout the Rocky Mountain region of the United States including Idaho, Wyoming, Montana, parts of Utah, Colorado, Nevada, Oregon, Washington, California and British Columbia. "It is most abundant in regions or localities where the predominating vegetation is low, brushy and more or less open, i.e., in areas where there is good protection for the small mammalian hosts of the larvae and nymphs and sufficient forage to attract the large

FIG 159.—The Rocky Mountain spotted fever tick, *Dermacentor andersoni*; male (left), unengorged female (right). × 3.5.

hosts, either wild or domestic, of the adult ticks. It is relatively quite scarce in heavily timbered areas or country of a strictly grassland, prairie type" Parker et al.[11]

Dermacentor andersoni Stiles may be recognized by comparison with Fig. 156. The adult ticks feed mostly on large animals, such as horses, cattle and sheep, also deer, bear and coyote; the larvae prefer to feed on rodents such as ground squirrels, pine squirrels, woodchucks, and chipmunks; the nymphs feed on the same host species as the larvae; all three stages may feed on animals of intermediate size such as jack rabbits, marmots and badgers. In the wilder parts of its range where there are no domesticated animals, the adult ticks feed on deer, elk, bear, mountain goat and coyote.

The life cycle of the Rocky Mountain wood tick is fully described by Cooley [12] and from his description the following summary is largely taken. Copulation takes place on the host, and when fully fed the greatly

distended female drops to the ground. The pre-oviposition period is about a week, after which egg-laying begins, continuing over a period of about three weeks. If undisturbed, the eggs pile up ahead of the female in one large mass, averaging some 6,400 eggs. The incubation period of the eggs requires about 35 days when the young hexapod seed ticks emerge and find suitable rodent hosts, feed for three to five days, drop off and molt in from 6 to 21 days, emerging as nymphs with eight legs. These nymphs, the progeny of overwintered adults, go into hibernation to come up for feeding the next spring when they seek larger sized hosts as already explained, to which they attach for feeding over a period of from four to nine days. When fully engorged, the nymphs drop to the ground and in 12 to 16 days and over, molt for the second time, emerging as adults Some of these adults may find hosts in the same summer in which they have emerged as adults, but by the time they have emerged, Cooley explains, the season has generally become hot and dry, making it necessary for them to seek protection under waste and vegetation. The "normal cycle" is therefore two years. The larvae are found feeding through the summer months, and while the adults disappear by about July 1st, the nymphs continue in diminishing numbers until late summer. Since man is usually bitten only by the adult ticks, danger from this source exists only from early spring to about July 1st.

Like other species of ticks, *Dermacentor andersoni* Stiles is remarkably resistant to starvation. Hunter and Bishopp [15] report that all unfed seed ticks hatching from a mass of eggs usually die within one month after the first eggs hatch if food is not available. However, in one instance a period of 117 days elapsed between the beginning of hatching of the eggs and the death of the last seed tick. (A later record by these investigators exceeded 317 days.) Unfed nymphs have been found to survive a period of one year and 11 days, and adults collected on vegetation during the spring months may survive for a period of 413 days without food.

Rocky Mountain spotted fever has been known in the Bitter Root Valley of Montana since 1872.[13] It is also known as "tick fever," "black fever," "blue disease" and "black measles." The most characteristic and constant symptom is the rash which appears about the second to the fifth day on the wrists, ankles and less commonly on the back, later spreading to all parts of the body. Parker [14] states that the rash is sometimes preceded by a mottled appearance of the skin. The symptoms most often complained of at the outset are frontal and occipital headache, intense aching in the lumbar region and marked malaise. The incubation period is from two to five days in the more severe infections and from 3 to 14 days in the milder ones. The fever develops rapidly in the more virulent infections and may register 104° and 106° F. and in fatal attacks may

reach as high as 108.4° F. In fatal infections death usually occurs between the ninth and fifteenth day. Because errors in diagnosis are easily made, laboratory tests are recommended. One of the common tests consists in the intraperitoneal injection of blood (1 cc. whole blood) into male guinea pigs. In positive tests the guinea pigs show scrotal swelling, reddening and sloughing of the skin.

In Idaho a mild type of the disease exists, with a mortality of about 1 to 3 per cent according to Stiles. In a report on spotted fever in California covering a period of from 1903 to 1916, Kelly [15] states, "that of the six cases in Modoc (County) one died, and of the thirty-two in Lassen (County) five terminated fatally, giving a mortality of 16 per cent. Thus the type of disease in California is apparently not so severe as in the Bitter Root Valley of Montana, nor as light as in Idaho."

The causal agent was discovered by Wolbach [16] in 1919 who named it *Dermacentroxenus rickettsi* in honor of Dr. Howard T. Ricketts, who made great contributions to our knowledge of both Rocky Mountain spotted fever and typhus fever and who gave his life in these investigations in Mexico. The several rickettsioses transmitted by lice, fleas, mites and ticks are caused by infectious agents known as rickettsiae, hence the causal agent of Rocky Mountain spotted fever is generally referred to as *Rickettsia rickettsi* (Wolbach).

Parker states that Rocky Mountain spotted fever is endemic in at least 39 of the 48 states of the United States. Since 1931 the disease has been reported from 26 of the Central and Eastern states. Outside of the Rocky Mountain region it is most prevalent in parts of Maryland, Virginia and North Carolina. The greatest number of cases occur in populations engaged in outdoor occupations, principally agriculture. Both sexes and all ages are subject to the disease. In the western part of the United States most of the cases are men, while in the eastern part of the United States more women and children contract the disease. Parker suggests that this is probably due to the fact that the eastern vector is a tick *Dermacentor variabilis* (Say), which infests the dog, a household animal. The Rocky Mountain wood tick is found far less frequently on dogs.

Tick transmission of spotted fever.—After a preliminary investigation Wilson and Chowning [17] in 1902 advanced for the first time the theory that a tick ("wood tick") acts as the natural vector of the disease. According to Ricketts (in 48th Biennial Rept. Montana State Board of Health, p. 106) as recorded by Hunter and Bishopp [18] "the first experiments which resulted in the proof of the transmission of spotted fever by a tick were conducted by Drs. McCalla and Brenton of Boise, Idaho, in 1905. In these experiments a tick which was found attached to a spotted fever patient was removed and allowed to bite a healthy person. In 8 days this person developed a typical case of spotted fever. The

experiment was continued by allowing the same tick to bite a second person. In this case again a typical case of spotted fever resulted."

The famous experiments of Dr. H. T. Ricketts [19] began in April, 1906. The more important published work of this lamented investigator has been brought together in a memorial volume [20] from which the following summary is made of his reports on spotted fever. First of all it was shown that the disease could be transmitted to guinea pigs by direct inoculation and that the duration of the fever and cutaneous phenomena resembled very closely the conditions as observed in humans. Hence, knowing the susceptibility of this species, it was used for further experimentation.

On June 19, 1906, a small female tick was placed at the base of the ear of a guinea pig inoculated intraperitoneally June 11 with 3 cc. of defibrinated blood of a spotted fever patient. The tick fed for two days on this animal and was then removed and kept for two days in a pill box and on June 23 placed at the base of the ear of a healthy guinea pig, the former animal dying on the same day with characteristic symptoms. On June 28 the second guinea pig showed decided rise in temperature, which continued high until July 5 and became normal on July 7. Proper controls were conducted and two guinea pigs which were in the same cage with the tick-bitten guinea pig for two weeks did not become infected, indicating that mere association did not result in contracting the disease. It will be noticed that Ricketts called the wood tick which he used *Dermacentor occidentalis* Neum. Evidently the species was actually *Dermacentor andersoni* Stiles.

In addition to many other successful experiments during the following year Ricketts found that the disease can be transmitted by the male [21] as well as by the female tick and that "one attack of the disease establishes a rather high degree of immunity to subsequent inoculation." Furthermore a collection of ticks taken in the field transmitted the disease to a guinea pig in the laboratory, indicating the fact that infective ticks occur in nature in small numbers.

It was also ascertained that "the disease may be acquired and transmitted . . . by the tick during any of the active stages . . . and that the larvae of an infected female are in some instances infective. . . . The disease probably is transferred through the salivary secretion of the tick, since the salivary glands of the infected adult contain the virus." The transmission is believed to be "biological rather than purely mechanical."

Experiments conducted by Moore (Ricketts, 1911, loc. cit., pp. 428–436) show that the "minimum duration of feeding necessary for a tick to infect a guinea pig was one hour and forty-five minutes The average time necessary seems to be about ten hours, while twenty hours were almost constantly infective." Maver (see *Ricketts, 1911, loc. cit., pp.*

440–444) in a series with other species of ticks found that spotted fever can be transmitted from infected to normal guinea pigs by nymphal *Dermacentor variabilis* (Say) infected as larvae, by adult *Dermocentor porumapertus marginatus* Banks and nymphs of *Amblyommo omericanum* (Linn.). Ricketts showed transmission by adult *Dermacentor albipictus* (Packard) infected as nymphs.

The infection in nature.—Parker points out that field observations made in eastern Montana in 1916 and 1917 suggested that under the "epizootilogic" conditions cancerned, some agent other than *Dermacentor andersoni* Stiles was likely involved in the natural maintenance of the virus. In 1923 Parker [22] established the fact that the rabbit tick, *Haemaphysalis leporis-palustris* (Packard), is capable of transmitting the infection from rabbit ta rabbit and also that infected rabbit ticks accur in nature. A third important fact was established, namely that the infection is transmitted by infected female ticks to the egg as in the case of *Dermocentor andersoni* Stiles. While the rabbit tick does not bite man, it is important indirectly in that it is a potent vector under natural conditions and is furthermore the only known vector which occurs in all parts of the United States. The infection carried by this tick is reported by Parker to be extremely mild. Rabbits of all species studied are hosts of both wood ticks and rabbit ticks.

The American dog tick, *Dermacentor variabilis* (Say), was proved to be a carrier of the eastern type of Rocky Mountain spotted fever in 1931 by Dyer, Badger and Rumreich,[23] who bred larvae from eggs. The larvae were fed on a guinea pig infected with the eastern type of the disease and after engorgement were allowed to molt and the nymphs were fed to engorgement on a non-infected guinea pig and were then ground up and injected into fresh guinea pigs, thus establishing a strain of virus in guinea pigs. The results of these investigators canfirmed the early work of Ricketts and Maver (1911); they also proved that transmission is hereditary. Parker [24] 1937 reports successful stage-to-stage and generation-to-generation transmission with *Dermacentor occidentalis* Neum, the Pacific coast tick, and *Rhipicephalus sanguineus* (Latreille), the brown dog tick. In the latter species virus continuity was shown from larval ticks of one generation through six successive stages to adults of the next. In *Amblyomma americanum* (Linn.), Maver (1911) had already reported larva-to-adult continuity, and transmission from female to larvae was accomplished by Parker. With *Amblyomma cajennense* (Fabr), the Cayenne tick, transmission from larvae to adults has been shown, and for *Dermacentor parumapterus marginatus* Banks, a rabbit tick, transmission from nymphs to adults was shown by Maver (1911) and continuity from larvae to nymphs as well as survival of the virus in adults was shown by Parker (1937). Parker states that these

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apparently progressively less effective as the virulence of infecting strains is increased."

Colorado tick fever.—Parker (1937, loc. cit.) states that in many parts of the Rocky Mountain region, febrile reactions, which do not appear to be provoked by any recognized tick-borne disease agent, are of relatively frequent occurrence following the bite of *Dermacentor andersoni* Stiles. The most definite of these symptom complexes is most commonly referred to as "Colorado tick fever." It is a "disease of a remittent type and is commonly characterized by the occurrence of two febrile periods, each of two to four days' duration, with a remission period of one to several days between. The outset is sudden and the *fastigium* is often reached within the first 24 hours. *There is no rash.* Symptoms other than fever are malaise, chilly sensations, severe headache, non-productive conjunctivitis, photophobia and generalized muscular and joint pains with particularly severe aching in the lumbar region. The malaise is usually intense. Constipation is the rule. The temperature often reaches 104° to 105° F. or over, but may not exceed 101° to 102° F. The pulse rate is frequently 120 to 130. In most instances, though not always, the symptoms are more severe during the first febrile period. . . . It is non-fatal."

Tick transmission of tularaemia.—Parker [29] writes that tularaemia infection in ticks was suspected in numerous instances during the seasons of 1922 and 1923 on account of the gross lesions at death in guinea pigs into which such ticks had been injected. Confirmation was made by cultivation of *Pasteurella* (=*Bacterium*) *tularensis* from guinea pigs in which the tick strain had been propagated. *Dermacentor andersoni* Stiles collected from nature proved infective; also experimentally, infection acquired by immature ticks was passed on to subsequent stages of the same generation. Later Parker and Spencer [30] (1926) demonstrated congenital transmission. This is believed to be the first record of hereditary transmission of a known bacterial infection. Probably several species of ticks are able to transmit the infection; *Dermacentor occidentalis* Neum. and *Dermacentor variabilis* (Say) have been incriminated. *Haemaphysalis leporis-palustris* (Packard), the rabbit tick, is responsible for the maintenance of the infection in nature. *Pasteurella tularensis* has been recovered both from infected sage hens in Montana and from the tick, *Haemaphysalis cinnabarina* Koch, taken from the same birds. Recently Davis and Kobls [31] (1937) discovered evidence indicating that *Ixodes ricinus* var. *californicus* Banks may be a carrier of tularaemia to human beings.

Tick paralysis.—A paralysis of sheep and calves attributable to ticks has been known in Australia according to Henning [46] vol. II, p.

619) since 1843. Paralysis reported as "acute ascending paralysis" associated with tick bite was described in 1912 by Temple [32] in Oregon The case reported was that of a child in which there was a complete paralysis of the motor and sensory nerves extending to the knees, causing inability to stand in the morning after retirement in apparent good health On the third day the paralysis had involved the nerves of the throat and the child was unable to swallow or speak. Upon removal of two fully engorged ticks from the occipital region recovery was rapid and complete within a week. The ticks were not positively identified, though they were presumably *Dermacentor andersoni* Stiles. In 1913 Hadwen [33] reported cases of paralysis in sheep following the bite of *Dermacentor andersoni* Stiles (*D. venustus* Banks). He also cites excerpts from letters to Todd (Canadian Med. Assoc. Journ. 1912) from physicians in British Columbia indicating frequent occurrence of paralysis in children following tick bite. The ticks were commonly removed from the nape of the neck. This tick has a decided preference for biting along the spinal column.

In 1913 Hadwen and Nuttall [34] report having produced paralysis experimentally in the dog by means of *Dermacentor andersoni* Stiles (*D venustus* Banks). The paralysis was the same as in sheep. In the experiment reported paralysis was caused by a single tick in eight days. The authors state "on the hypothesis that the symptoms are due to *toxins* given off by the tick, 'the period of incubation' might be explained on the supposition that it is only when the tick commences to engorge or feed rapidly, some days *after* it has become attached, that it gives off the hypothetical toxin in its saliva in sufficient quantity to produce pathogenic effects."

Tick paralysis is widely distributed in the western United States and Canada adjacent to the Rocky Mountains and coincides with the distribution of *Dermacentor andersoni* Stiles. Hearle, 1938 (loc. cit.), states,

> "As an index of the wide distribution of this trouble in British Columbia, incomplete returns from medical practitioners indicated that nearly 150 human cases had been noted in the province . . . cases in sheep have been particularly numerous, and many deaths have resulted. Cattle are usually less susceptible, but trouble from tick paralysis has been noted from time to time, and in the spring of 1930 a serious outbreak in steers was investigated; over 100 paralysis cases, sixty of them fatal, being noted in one herd. We know of only one equine case. In sheep districts where this trouble is prevalent, flock masters are obliged to examine their animals frequently for the purpose of removing the offending
>
> head, the region of the spine and along the neck, since this is where they mainly become attached."

Ixodes holocyclus Neumann causes paralysis in calves, sheep and

dogs in Australia. According to Ross[35] this condition is caused only by the mature engorging female tick two days before it is ready to drop from the host. He used the dog in his experimental work.

The Texas cattle fever tick, *Boöphilus annulatus* (Say) (*Margaropus annulatus* Say) (Fig. 160) is normally restricted to North America south of the 37° latitude into parts of Mexico. It is typically a cattle tick, although it occurs at times in smaller numbers on deer, sheep, horses, mules, and other animals. The bison is evidently also a suitable host.

Fully engorged females range in length from 10 to 12 mm., while the male ranges from 3 to 4 mm. The body of the female is about equally rounded both posteriorly and anteriorly with a slight median incurving. The anterior pair of legs is set well out on the shoulders away from the capitulum (in *Dermacentor* close to the capitulum). The palpi are very short and stalky, so that the entire capitulum or head is inconspicuous The relatively small (about 1 mm. long) scutum or shield is solid chestnut-brown in color. This is commonly the only species of tick in some localities with a chestnut-brown scutum. Two other species of ticks with a chestnut-colored scutum occur occasionally with the Texas fever tick, namely the "Lone Star Tick," *Amblyomma americanum* (Linn.) which has, however, a distinct silver white circular spot at the posterior end of the scutum, and *Ixodes ricinus* (Linn.) and its varieties, e.g., *Ixodes ricinus* var. *californicus* Banks, in which the capitulum is long, and the anterior pair of legs are attached close to it. Other more technical diagnostic characters must, of course, be taken into consideration.

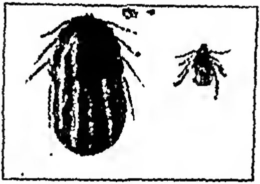

FIG 160.—The Texas fever tick, *Boöphilus annulatus*; female (left) and male (right) × 3.5.

The stigmal plates of *B. annulatus* (Say) are nearly circular; the porose areas are elliptical and far apart.

Economic importance.—In 1906 it was estimated that the annual losses to the South (U. S.) occasioned by the "cattle tick" directly and indirectly prior to 1906 amounted to $130,500,000.[36] This sum included (1) death, from Texas fever, of pure-bred cattle imported from the North for breeding purposes; (2) death, from Texas fever, when cattle reared in isolated tick-free areas are unintentionally or accidentally placed with ticky cattle, or on tick-infested areas; (3) death of native cattle from excessive parasitism and fever, occasioned by the ticks; (4) universal loss of weight by all tick-infested cattle, and their failure to gain flesh at

a rate great enough to make beef production profitable; (5) the lower price which "Southern" cattle bring upon the market, regardless of how perfect their condition may be; (6) sterility induced in high-grade cattle by tick infestation; (7) the expense of maintaining the Federal quarantine for the protection of the North against invasion by the tick, and the added expense of maintaining quarantine pens for southern cattle shipped North for slaughter; (8) the discouraging effect on the breeding of purebred cattle in the South by reason of southern breeders not being allowed to exhibit in northern show rings; (9) by no means least, the potential loss in fertility of southern farm lands due to a one-crop system which, with the tick eradicated, would quickly give way to a diversified agriculture which would conserve and increase the fertility of soils; (10) shrinkage in milk production of ticky cattle.

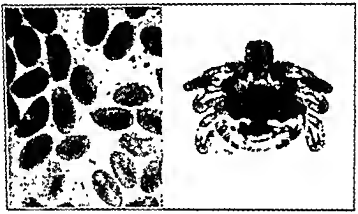

Fig. 161.—Eggs (left), larva (right); of the Texas fever tick, *Boöphilus annulatus*. × 50.

From 1906 when coöperative tick-eradication work was undertaken between the U. S. Bureau of Animal Industry and State authorities, to December, 1918, a total of 458,529 square miles of territory was released from quarantine against Texas cattle fever, which speaks well for the methods employed.[37] Less than one-fifth of the area under quarantine in 1906 remains so today.

Life history of Texas fever tick.—*Boöphilus annulatus* (Say) is a one-host tick The life history may be divided into two phases—(1) the *parasitic* phase during which the tick is attached to the host and terminates when the mature tick drops to the ground after fertilization; (2) the *non-parasitic* phase when the tick is on the ground. After the mature female tick drops to the ground, there is a pre-oviposition period of three or four days to perhaps a month. Oviposition usually begins about 72 hours after the tick drops and continues usually for eight or nine days but may be greatly prolonged due to adverse temperature.

The maximum number of eggs deposited by a female tick according to Graybill [38] was 5,105, minimum 357, with an average ranging from 1,811 to 4,089. The incubation period, also dependent on temperature, ranged from 19 days in summer to 180 days in the early autumn, with the average of 43.6 days for April, 26.3 days for May, 24.5 days for June, 20.5 days for July, 21.2 days for August and 35.9 days for September. The hatching period depends on the time when the eggs are laid, the eggs first deposited ordinarily hatching first. The seed ticks (Fig. 161) on hatching are very active and climb on to blades of grass or other objects which they ascend to the top and remain clustered until a suitable host animal brushes against them to which they attach themselves. The time during which the seed ticks remain alive, i.e., longevity of the newly

TABLE XVII

COMPARISON OF THE LIFE CYCLE OF A WOOD TICK AND THE TEXAS CATTLE FEVER TICK

Wood tick (*Dermacentor* sp.)	Texas cattle fever tick (*Boöphilus annulatus*)
I. Adult tick becomes engorged on host animal and drops to ground	Adult tick becomes engorged on host animal and drops to ground
II. Adult tick begins egg laying (3,000 ± eggs) after 3–5 days	Adult tick begins egg laying (3,000 ± eggs) after 3–5 days
III. Seed ticks hatch from eggs in about 30 days	Seed ticks hatch from eggs in about 30 days
IV. Seed ticks bunch on grass and await coming of host animal, from one day to several weeks	Seed ticks bunch on grass and await coming of host animal from one day to several weeks
V. After feeding 7–12 days seed ticks drop to ground and molt	After feeding 7–12 days seed ticks molt on host animal
VI. Nymphs crawl up on grass and await coming of second host animal from one day to several weeks	
VII. Ticks get on second host animal and feed 5–10 days, then *drop to ground* and molt second time	Nymphs feed 5–10 days, then molt second time *on* host animal and the newly emerged mature ticks mate
VIII. Mature unengorged ticks crawl up on grass and await coming of third host animal from one day to several weeks	Adult ticks feed 4–14 days to engorgement, then drop to the ground and lay eggs
IX. Adult ticks mate and feed 5–8 days to engorgement, then drop to the ground and lay eggs	

hatched ticks, again vories considerably, depending on temperature; the longevity for April ticks was found to be 65.1 days, May 62.3 days, June 65.1 days, July 38 6 days, August 84 9 days, October 167.4 days. The total average ranged from 86.9 days for June to 279.6 for October.

The three stages considered in the parasitic period of the ticks are larval (seed tick), nymphal and adult. As Graybill has well said, "The duration of each of these stages and the duration of a single infestotion upon cattle during different portions of the year are of great practical importance. Upon the duration of an infestation depends the time animals must be kept on the tick-free fields in order to become free from ticks." After the seed tick has attached itself to the host, the larval period ranges from 5 to 10 days, the nymphal period from 5 to 20 days, and the adult females from 5 to 35 days, with a total period of infestation, including the time for molting twice, which is accomplished on the host, from 20 to 65 days. The entire life cycle may be completed in about 40 days under most favorable conditions, usually nearer 60 days under natural conditions.

Texas cattle fever.—Red water, splenic fever, bloody murrain, Mexican fever, tick fever, etc., are names given to a widely distributed disease of cattle, endemic in southern Europe, Central and South America, parts of Africa, Mexico, the Philippines, and the southern United States where it bas been known for more than a century, haviog been introduced into this country probably from Europe. The causal organism is *Babesia bigemina* (Smith and Kilbourne).

The name Texas fever became attached to the disease in the United States because of the large herds of cattle which were driven northward from Texas and gave a certain disease in some mysterious manner to northern cattle that crossed the trail of the southern cattle. The first account of the disease was given by James Mease in 1814 before the Philadelphia Society for Promoting Agriculture. In 1879 Salmon began an investigation of the disease; ond in 1889 Theobald Smith made his epoch-making discovery of the intracorpuscular protozoan parasite inhabiting the blood of the diseased cattle. Immediately thereupon followed the experiments of Smith and Kilbourne, on suggestion of Salmon, which proved the disease to be tick-borne, a suspicion held os early as 1869 according to Smith and Kilbourne. Until that time (1889) infection was variously attributed to saliva, urine or feces.

The disease may assume either an acute or chronic form, the acute occurring during the summer months and the chronic during the autumn and early winter. The symptoms of the acute form are as follows: The temperature often rises to 106° to 108° F. within twenty-four to forty-eight hours. The sick animal leaves the herd, stands with arched back, head lowered and ears drooping, the muzzle dry, appetite lost ond rumi-

nation stopped. There is constipation during the first stage of the disease, which may give way to diarrhea later. The manure is frequently stained with bile and may be tinged with bloody mucus; the urine is often very dark red or coffee-colored. The blood becomes thin and watery, so that when making an incision into the tip of the ear and allowing the blood to flow over the hand it does not stick to the hand as does the blood from a healthy animal.

Vast numbers of *red blood corpuscles* are destroyed by the parasites, which accounts in a measure for the reddish color of the urine through the elimination of haemoglobin by the kidneys; and it is believed that the excessive work that the liver has to perform in attempting to transform the excess of destroyed corpuscles into bile, causes this organ to become deranged in function, and eventually a complete stagnation may result with fatal termination. Mortality ranges from 50 to 75 per cent.

The chronic form of the disease according to Mohler [39] shows all the symptoms of the acute type, but in a milder degree. The temperature usually remains about 103° and never exceeds 105° F. There is loss of [illegible] nin in the urine [illegible] le and bloodless mucous membranes, is also present, but haemoglobin is not usually excreted by the urine; hence the red-water symptom is absent. There is also excessive loss of flesh and before the end of the attack, the affected animal is greatly emaciated. Although death rarely occurs, the value of the animal is much reduced.

Experimental evidence.—In 1888 an "investigation into the nature, causation and prevention" of the disease was undertaken by the United States Department of Agriculture, Bureau of Animal Industry, under the direction of D. E. Salmon. The work was done by Theobald Smith [40] and F. L. Kilbourne and marks a most important epoch in our knowledge of protozoan diseases and in preventive medicine.

During a period of about four years of almost continuous investigation, the problem was exhaustively studied in both the field and in the laboratory. The field experiments were carried out along three different lines:

"(1) Ticks were carefully picked from Southern animals so that none could [illegible] The object of this group of experiments was to [illegible] stock on [illegible]

Northern cattle were infected by [illegible] ficially, i e., in closed dishes in the laboratory" (Smith and Kilbourne, [illegible] loc. cit.).

continue on the infested pasture and treating them at regular intervals with agents destructive to ticks, such as arsenical dips.

Dipping.—Proper dipping of all cattle in a given area at 14-day intervals when tick development is rapid, beginning during March and continuing until November, according to Ellenberger and Chapin (loc. cit.) will result in complete eradication of the cattle tick. The reason for this

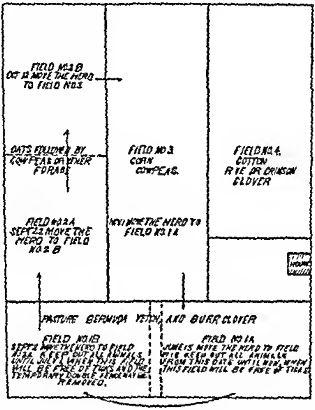

FIG. 163.—Plan for freeing cattle and pastures from ticks by rotation, requiring four and one-half months. (Redrawn after Graybill.)

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Arsenical cattle dips found ... ous. All arsenical cattle dips contain ar... e as ... ickicide, but since traight arsenious oxi... ly sol..., sodium carbonate r hydroxide is neces... it in... this way the white rsenic is changed t... nite. ... rsenical cattle e now readily av...

Pasture rotati ... ti ... re rotatio

which show no differentiation between the sexes. The gametes become associated in pairs, the individuals of which eventually fuse to form the zygote. The zygote becomes a motile oökinete which passes through the thin wall of the gut and penetrates the contiguous reproductive organs. The ova of the tick are invaded by the oökinetes which round up and grow to form *sporonts.* The sporont secretes a cyst within which it divides to form naked sporoblasts. The sporoblasts form multinucleate sporokinetes which migrate and are carried by cell proliferation throughout the tissues of the developing tick; some of the sporokinetes come to occupy the *anlagen* of the salivary glands The sporokinete undergoes fragmentation to form the minute infectious sporozoites." (Fig. 162.)

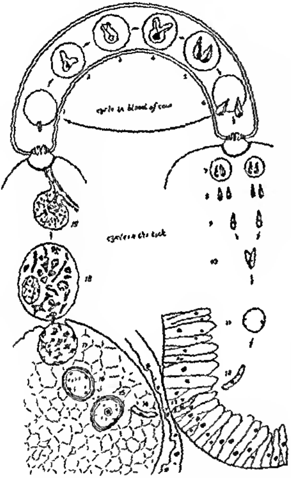

FIG 162.—A schematic diagram of the life-cycle of *Babesia bigemina* 1 6, the cycle in the blood of the bovine host, showing binary fission, 7, parasite just taken into gut of tick; 8, freed trophozoites in the gut of the tick; 9, vermicule-like isogametes; 10, beginning of syngamy, association of the gametes in pairs; 11, completion of syngamy; 12, motile zygote, or ookinete; 13 14, oökinete passing through wall of the gut of the tick, through the oviduct, and entering the ovum; 15, sporont formed by the rounding-up and growth of the ookinete; 16-17, formation of sporoblasts; 18, sporokinetes in one of the large cells which are destined to form part of a salivary acinus; 19, sporozoites, in the salivary gland (a single acinus shown) of the larva of the tick, whence they are transferred into the blood of a new host. (After Dennis.)

Texas fever tick control.—Methods for the eradication of the Texas cattle fever tick are described in detail in publications of the United States Department of Agriculture. Ellenberger and Chapin [43] divide the methods of control under the heading of (1) *direct* method, consisting of exclusion of cattle, horses and mules from pastures until all ticks have died from starvation. This plan is seldom followed because the owner is usually unwilling to give up the use of a pasture even temporarily; also the necessary tick-free fields are seldom available for the rather complicated method of pasture rotation explained in a later section. (2) *Indirect* method consists in permitting the cattle and other animals to

continue on the infested pasture and treating them at regular intervals with agents destructive to ticks, such as arsenical dips.

Dipping.—Proper dipping of all cattle in a given area at 14-day intervals when tick development is rapid, beginning during March and continuing until November, according to Ellenberger and Chapin (loc. cit.) will result in complete eradication of the cattle tick. The reason for this

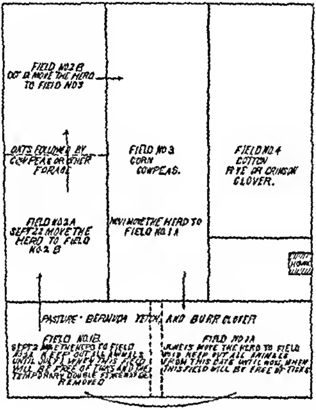

FIG 163.—Plan for freeing cattle and pastures from ticks by rotation, requiring four and one half months (Redrawn after Graybill)

repeated dipping is that this will result in the destruction of all ticks that get on the animals before they have had a chance to mature and drop off. The cattle act as collectors of ticks which will be destroyed regularly by dipping at the intervals designated.

Arsenical cattle dips have been found most efficacious All arsenical cattle dips contain arsenious oxide as the active tickicide, but since straight arsenious oxide is so slowly soluble in water, sodium carbonate or hydroxide is necessary to bring it into solution. In this way the white arsenic is changed to sodium arsenite. Proprietary arsenical cattle dips are now readily available.

Pasture rotation.—Exterminating ticks by pasture rotation is based

on the time required to kill the ticks by starvation. Inasmuch as the longevity of ticks depends on moisture and temperature mainly, local conditions affecting the same must be taken into consideration. Cold and moisture prolong life, while dryness and heat shorten the same.

In pasture rotation the cattle are kept off a given pasture for a given length of time, after which they are moved to a third area, etc., until all ticks have matured and have dropped from the cattle and have died from starvation on the earlier plots. Thus a field should be divided into three or more plots each separated by means of two fences about fifteen feet apart to reduce the opportunity of ticks to crawl from one plot to the other.

Various plans requiring from four and a half to eight months have been devised to free both cattle and pasture from ticks. Thus a plan requiring four and one-half months is described by Graybill [44] (Fig. 163). He advises dividing the pasture in the middle by two lines of temporary fencing fifteen feet apart. This is to be done some time in the spring. The herd is first kept in field No. 1A, and is then removed, on June 15, to field No. 1B, and on September 1 to field No. 2A. The cattle must remain twenty days on fields 2A, 2B, and 3. At the end of this time, which would be November 1, all the ticks will have dropped and the herd is returned to field No. 1A, which has become free from ticks in the meantime. Field No. 1B becomes free from ticks July 1 of the following year, when the double fence between 1A and 1B may be removed and the cattle may then (and not before) graze over both fields. By August 1 the entire farm will be free from ticks.

Graybill advises as above that double fences be built between all the fields, when practicable, in order to prevent ticks from getting from one field to another. In place of the extra line of fence the next best thing would be to "throw up several furrows with a plow on each side of the dividing fences." If streams run through the farm or the slope of the land is considerable, so that ticks may be washed from field to field, he advises arranging the fields so that drainage is from field No. 1A to No. 1B, and from No. 3 toward fields Nos. 2A and 2B.

East Coast fever is a highly fatal disease of cattle along the East Coast of equatorial Africa. The mortality may run over 90 per cent. The disease is caused by the protozoön, *Theileria parva* (Theiler), and is therefore a form of piroplasmosis (theileriosis) though unlike red water it is not readily transmitted by means of blood inoculations, nor is there jaundice or haemoglobinuria. A very characteristic symptom is swelling of the superficial lymphatic glands.

The incubation period varies from 9 to 19 days and is usually from 10 to 15 days. The disease is transmitted by several species of ticks as shown by Lounsbury.[45] He first proved the adult brown tick, *Rhipicephalus*

appendiculatus Neum., to be a vector, and later showed that the disease may also be transmitted by the Cape brown tick, *Rhipicephalus capensis* Koch, and the red tick, *Rhipicephalus evertsi* Neumann.

Henning [46] states that unlike red water, East Coast fever is not transmitted from the adult female tick to the larva through the egg, but only by an adult tick which became infected during its nymphal stage, or by a nymph that became infected during its larval stage While *Rhipicephalus appendiculatus* Neum., *R. capensis* Koch and *R. simus* Koch are three-host ticks, *R evertsi* Neum. is a two-host tick, hence as the tick remains on the same host during both its larval and nymphal stages transmission of the infection is possible only during the adult stage. The infection is not transmitted through the egg. Lounsbury and Theiler both found that ticks of the three-host species which have sucked infected blood during their larval stage can transmit the infection only during their nymphal stage; i.e., whether the nymph feeds on either a susceptible or non-susceptible host, infectivity is lost. A single tick can transmit the infection only once, and that during the stage that follows the one having had the infectious meal.

Equine piroplasmosis.—At least two types of piroplasmoses are found in horses, mules and donkeys, namely true equine piroplasmosis, traceable to *Babesia caballi* (Nuttall), occurring in Africa, Russia, Transcaucasia and probably Siberia, and secondly a similar though distinct disease traceable to *Nuttallia equi* (Laveran) occurring in Transcaucasia, Italy, Africa, India and South America (Brazil). *Babesia caballi* is transmitted by *Dermacentor reticulatus* (Fabr.) in Russia; and *Nuttallia equi* is transmitted by *Rhipicephalus evertsi* Neum. in South Africa.

Canine babesiasis (piroplasmosis), also known as "malignant jaundice" of dogs, is prevalent in southern Europe, Asia, South Africa, and recently in the United States (Florida). The causative organism is *Babesia canis* (Piana and Galli-Valerio) and the carrier is *Rhipicephalus sanguineus* (Latr.) in India, southern Europe, and the United States; *Haemaphysalis leachi* (Audouin) is a South African vector, and *Dermacentor reticulatus* (Fabr.) and *Ixodes ricinus* (Linn.) transmit the infection in southern Europe. Brumpt and Larrousse [47] have shown that *Dermacentor andersoni* Stiles can carry the disease. The infection is hereditary in the tick, but transmission to the dog is effected by the bite of the adults, but not by the larvae and nymphs according to Brumpt.[48] The incubation period varies from 10 to 20 days. Sanders [49] recently (1937) reported that *R. sanguineus* (Latr.) is by far the most common species encountered in kennels and on animals affected with canine babesiasis in Florida.

Sanders (loc. cit.) states that the acute form of this infection is not

difficult to diagnose; "the high temperature, increased pulse and respiration, progressive anemia, jaundice, the history of tick infestation and the demonstration of the causal organism are usually observed."

Heartwater is a dreaded disease of South African sheep, goats and cattle, and is caused by *Rickettsia ruminantium* (Cowdry). It is carried by the "bont" tick, *Amblyomma hebraeum* Koch.

Henning (Animal Diseases of South Africa, vol. II, p. 545) states that the bont tick may subsist on any warm-blooded animal; it has been found during all its stages on man, all species of domestic animals and several species of antelopes. Bovines are its favorite host. This tick may lay as many as 18,000 eggs. The tick becomes a vector of the infection only after it has sucked blood from a diseased animal, i.e., hereditary infection does not occur, hence the newly hatched larvae are not infectious. *Amblyomma variegatum* (Fabr.) is able to transmit the infection in the adult stage.

Bovine anaplasmosis.—Anaplasmosis is an important and practically world-wide infection of cattle caused by minute punctiform blood parasites described by Theiler in 1910 as *Anaplasma marginale* with the organism at or near the periphery of the cell and *Anaplasma marginale* variety *centrale*, a somewhat smaller body, located approximately in the center of the red corpuscle.

Anaplasmosis is described by Stiles [50] as an acute, subacute, or chronic, febrile, infectious, protozoan disease, characterized by loss of flesh, labored breathing, suspension of milk flow, anemia, jaundice, and marked degenerative changes in the red blood corpuscles owing to the activity of the microscopic parasites. The average mortality ranges from 30 to 50 per cent in the animals affected.

Rees [51] records a total of ten species of ticks which have been incriminated by various investigators in the transmission of anaplasmosis; viz., *Boöphilus annulatus* (Say), *B. decoloratus* (Koch), *B. microplus* (Canestrini), *Rhipicephalus simus* Koch, *R. bursa* Canestrini et Fanzago, *Ixodes ricinus* (Linn.), *Hyalomma lusitanicum* (Koch), and three others which have been incriminated by himself, *Rhipicephalus sanguineus* (Latreille), *Dermacentor variabilis* (Say), and *D. andersoni* Stiles.

In 1936 Herms and Howell [52] reported five cases of tick transmission, two non-hereditary with *Dermacentor albipictus* (Packard) and *D. andersoni* Stiles, and three in which the infection passed through the eggs of the western dog tick, *Dermacentor occidentalis* Neum. (Fig 164), the offspring being infective in both the larval and nymphal stages. In the congenital transmissions from the time the infective larval ticks were applied to the host animal to the time that marginal bodies first appeared in the blood the elapsed time was 37 days, 32 days and 123 days respec-

tively. In the two non-hereditary transmissinns the elapsed time was 28 and 29 days.

That deer, the southern black-tailed deer, *Odocoileus hemionus columbianus* (Richardson), and the Rocky Mountain mule deer, *Odocoileus hemionus hemionus* (Rafinesque), may serve as reservoirs for anaplasmosis was proved by Boynton and Woods in 1933.[53]

To free dogs of ticks a thorough application of derris powder or wash is recommended by Bishopp and Smith.[54] These authors state that derris when used as a powder should have a rotenone content of at least two per cent and should be applied at intervals of two or three days. A dip or wash can be made by dissolving an ounce of soap in a gallon of water and adding two to four ounces of derris powder of which the rotenone content is four per cent. The dip should be applied at intervals of five or six days.

The application of the powder is simpler, and kills the ticks with which it comes in contact, but a more thorough covering is secured when a wash or dip is applied. The wash also has a longer repellent action.

Coal-tar creosote as used for cattle dip may also be used.

FIG 164—Western dog or wood tick, *Dermacentor occidentalis.* × 2 5.

FAMILY ARGASIDAE

Relapsing fever ticks belong to the genus *Ornithodoros* and are characterized in common with other members of the family Argasidae by the absence of a scutum and the leg-like palpi associated with the ventral capitulum. The genus *Ornithodoros* is distinguished from the genus *Argas* by the distinctly rounded sides of the body, whereas in the latter (*Argas*), the narrow marginal border is always distinctly visible even when the tick is fully replete. *Ornithodoros* ticks have the "anterior end more or less pointed and hood-like. Margin thick and not clearly defined, similar in structure to the rest of the integument, and generally disappearing on distention Capitulum subterminal, its anterior portions often visible dorsally in the adult. Disks present or absent; but when present not arranged radially (see *Argas*). Certain fairly constant grooves and folds on the venter, namely, a coxal fold internal to the coxae, a supracoxal fold external to the coxae, a transverse pre-anal and a transverse post-anal groove or furrow, and a post-anal median groove. Eyes present or absent" (Nuttall and Warburton).

Ornithodoros moubata (Murray), the African relapsing fever tick (Fig 165), occurs only in Africa. It occurs in native huts, hiding in dust and thatch It feeds chiefly at night and engorges rapidly as does the bedbug. It is an eyeless species with a specific arrangement of the

"humps" on the protarsus of the first pair of legs, being "subequal and tooth-like." The adults measure from 8 to 11 mm. in length and about 7 mm. in breadth. The color varies from dusty brown to greenish brown in living specimens and turns reddish or blackish brown in alcohol. Eggs are deposited in batches of from 35 to 340 at intervals after blood meals during the lifetime of the female. The maximum number of eggs laid by one female was 1,217 according to Jobling.[55] Hatching takes place in from 7 to 11 days and over, depending on temperature. Experimentally, at least, the active larvae attach themselves to a warm-blooded host, remaining attached for nearly a week, when they become disengaged and molt, the nymph now appearing. The nymphs feed at intervals, molting once or twice between each meal; there may be six to nine molts and apparently young females molt even after sexual maturity has been reached, according to various observers, and individuals may remain infective for over a year. Wellmann has observed that this species attacks a wide range of animals besides man, notably pigs, dogs, goats and sheep; Nuttall found them to feed in his laboratory on rabbits, mice, rats, monkeys and fowls.

Fig. 165.—African relapsing fever tick, *Ornithodorus moubata* × 3

Tick-borne relapsing fever.—Although we are told that the natives in many parts of Africa have dreaded tick bites for many generations, David Livingstone, the explorer, in 1857 was the first to report upon the evil effects following the bite of a tick which was named *Ornithodoros moubata* (Murray, 1877). It was not, however, until 1904 that Ross and Milne,[56] and in 1905 Dutton and Todd,[57] reporting from Uganda and the Congo, and almost simultaneously Robert Koch from German East Africa, gave us the knowledge that these evil effects were due to an endemic relapsing fever and that the tick named by Murray, and which was so dreaded by the natives, was a vector of the spirochaetal agent, *Spirochaeta duttoni* Novy and Knapp.

The symptoms of the disease are described by Nuttall (loc. cit., 1908), as follows:

"Headache (especially at the back of the head), vomiting, abdominal pains and purging, with severe fever, a pulse of 90 to 120, dry hot skin, congested eyes and shortness of breath After a period of fever lasting about *two days*, there [illegible] fresh attack soon follows These relapses occur [illegible] *5 or 6 in num-* [illegible] weak condition [illegible] occurs in about [illegible] 6 per cent of the cases."

How infection is transmitted.—Dutton and Todd (loc. cit.) proved that the infection is transmitted to the offspring of the female tick through the egg. The newly hatched larvae were proved to be infective. Once infected the tick remains so and the infection may be transmitted at least as far as the third generation. The infection is transmitted when the tick bites, but infection is believed to be accomplished principally by means of infectious tick feces; the coxal fluids are believed to play an important rôle. The attack of fever takes place in the human in from 5 to 10 days after the tick has bitten. Feng and Chung [58] report that "shortly after the spirochaetes are ingested by the ticks they penetrate the stomach wall and reach the body cavity as evidenced by finding spirochaetes in the legs six hours after the infective feed. . . . The spirochaetes gradually disappear from the stomach and reach the body cavity with the result that from the twelfth day onwards no more spirochaetes could be found in the stomach contents. . . . From the body cavity the spirochaetes invade the salivary glands, the coxal glands, the reservoirs and the nerve ganglion . . . The constant presence of numerous spirochaetes in the acini of the salivary glands and the finding on several occasions of spirochaetes actually inside tha small salivary ducts suggests that besides the coxal fluid the bite alone may also be infective. . . . (The spirochaetes) multiply by transverse division after they have penetrated the stomach wall and reached the body cavity and other organs of tha tick. . . . Mice inoculated . . . with feces remained sterile."

Tick-transmitted endemic relapsing fever in the United States was first reported by Weller and Graham [59] in central Texas in 1930. According to Parker et al. (1937, loc. cit., p. 433) it is now apparent that cases of relapsing fever reported by various investigators in Colorado, California and Texas, previous to that time and in Arizona, Nevada, Kansas, New Mexico, Washington, and possibly Montana were all of endemic origin. The transmitting agent has been identified in only the following of the states listed above, *Ornithodoros turicata* (Dugès) in Texas, Arizona and possibly Kansas, and *Ornithodoros hermsi* Wheeler in California and Nevada.

Weller and Graham (loc. cit.), 1930, found a cave in the Colorado River Valley of central Texas which was "literally alive with ticks, a handful of sand yielding thirty or forty of different sizes." The species was identified as *Ornithodoros turicata* (Dugès). The cave, it was reported, is "frequented by goats and sheep; also probably wild animals such as bats, foxes, skunks and rabbits" Some of the ticks were applied to three rabbits, allowed to feed for fifteen minutes and then crushed and rubbed into the abrasions. Spirochaetes were observed in the blood.

Tick transmission in California.—In 1921 Briggs [60] reported two cases of relapsing fever in which the infection had been contracted at

Polaris (Nevada Co.) on the Truckee River, California. It is evident that Briggs suspected lice because he remarks, "Many tramps, put off trains at Truckee, find a day or so of employment here, only to move on. It is quite evident, therefore, that there are great opportunities for the dissemination of vermin by a nomadic population." In a letter to Dr. Briggs under date of October 14, 1922, Dr. Mark F. Boyd states that prospectors sleeping in an abandoned cabin near Verdi, Nevada, were badly bitten by ticks, identified by Banks as *Ornithodoros talaje* (Guérin-Méneville). "The locality," he writes, "cannot be very far distant from the place where your cases received infection, at any rate close enough so that this species of tick would naturally demand consideration." In the light of later developments it is of interest to know that prospectors working in altitudes of 5,000 feet and over reported suffering from a disease which they called "squirrel fever."

Porter, Beck and Stevens [61] state that no further cases of relapsing fever came to the attention of the California State Department of Public Health until September, 1930, when Dr. George Stevens reported a case of a school teacher who had lived at Big Bear Lake (San Bernardino County) during July and August. In 1930 Major V. H. Cornell reported a case in which infection had been contracted at Lake Tahoe (Eldorado County) during July. In June, 1932, C. M. Wheeler, an assistant on field duty, contracted relapsing fever at Packer Lake (Sierra County) by accidentally smearing his fingers with blood from a Sierra chickaree squirrel (*Sciurus douglasii*) which with four others he had shot a few minutes previously.[62] The blood from the squirrels proved positive for spirochaetes (*Spirochaeta recurrentis* Lebert). Seven days after the accident he developed a proven case of relapsing fever.

On August 12, 1931, three specimens of mature undescribed *Ornithodoros* ticks were taken in a cottage near Brockway on Lake Tahoe (Eldorado County) at an elevation of approximately 6,000 feet where cases of relapsing fever had occurred about a month previously. In August, 1934, more ticks of the same undescribed species were collected in a relapsing fever cabin at Big Bear Lake at an elevation of about 5,700 feet. Other specimens were taken in various localities of the three counties already named (Eldorado, Placer and San Bernardino) at elevations of from 5,000 to 8,000 feet. This new species of tick was named *Ornithodoros hermsi* by Wheeler [63] in 1935 and at the same time Wheeler, Herms and Meyer [64] reported transmissions to a monkey and white mice by the bite of this tick.

Ornithodoros hermsi Wheeler (Fig. 166), the vector of relapsing fever in California, transmits the infection by the bite of both male and female ticks and in all stages of development. The proportion of infective larvae in hereditary transmission appears not to exceed one per cent.

Wheeler [65] reports that from 35 per cent to 48 per cent of non-infective ticks when allowed to feed as larvae on infected laboratory white mice were able to acquire the spirochaetes and transmit them to normal animals in some one or all of the subsequent developmental stages. One female tick has caused four infections in white mice during a period of about four months. Larvae from a presumably non-infective female tick produced infections, and conversely the larvae of an infective female may not be infective. The spirochaetes are usually present in the blood

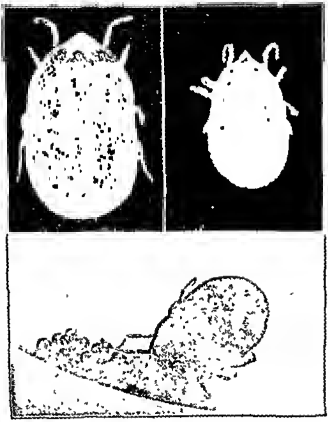

FIG. 166.—*Ornithodoros hermsi.* Mature female (top left), mature male (top right); lower figure shows female depositing eggs

of white mice about five days after being bitten by an infective tick. The *time elapsing before infected ticks transmitted* the infection depends, of course, on the time when the ticks were ready to feed again with molting intervening, this elapsed period was at the shortest 15 to 20 days.

To prove that *O. hermsi* Wheeler is able to transmit the infection to man by its bite, Wheeler [65] conducted a number of tests, with one positive transmission in seven tests.

The life history of *Ornithodoros hermsi* Wheeler (Fig. 167) as de-

scribed by Herms and Wheeler[67] is as follows: The very tiny light amber-colored eggs are deposited at intervals in batches of 12 to 140 from May to October and range well over 200 per female. A specific example follows: Female tick, No. 5, taken as a last-stage nymph August 17, 1934, deposited a total of 232 eggs in four batches, 98 (April 8), 73 (May 19), 49 (May 26), and 12 (June 12) with but one feeding (*i.e.*, after first batch was laid) between egg-layings, and died October 21, 1935. Under natural conditions the eggs are deposited in the hiding places of the ticks: in summer cabins the eggs are laid in such corners and crevices as afford protection to the ticks.

The incubation period at a temperature of 75° F. and 90 per cent humidity ranges from 15 to 21 days. The number of eggs and the percentage of larvae hatching seems to grow less in the later egg-layings, as high as 95 per cent for the first batches down to less than 50 per cent in the last. The first molt is usually accomplished within the egg; how-

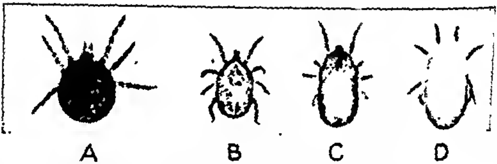

FIG. 167.—Immature stages of *Ornithodoros hermsi.* (A) larva; (B) first nymphal stage; (C) second nymphal stage; (D) third nymphal stage.

ever, the larva (seed tick) remains hexapod until after the second molt. After about three days the larva is ready to feed, remaining attached to the host for only about 12 to 15 minutes as is the case in later stages, although this attachment in the latter may be for from one-half to one hour in many cases. The larvae when fully engorged increase as much as three times in size and acquire a bright red color due to the imbibed blood. In this condition these tiny ticks have been referred to as a "strawberry seed insect" by persons living in relapsing fever areas. Molting takes place in about 15 days after feeding. With this molt the fourth pair of legs appears, and this stage is termed the first nymphal instar. The first nymphal stage may feed within a few hours after molting and again a period of 11 to 15 days elapses before the third molt and the appearance of the second nymphal instar. Then follows the third feeding and again an elapsed period, in this case about 10 to 32 days, before the fourth molt and the appearance of the third nymphal instar or even the adult may appear with this molt. Usually a fifth feeding and

a fifth molt are necessary before sexual maturity is reached. Egg-laying may begin in about 30 days after the last molt, fecundation taking place in a few days after reaching maturity The cycle from egg to egg under our laboratory conditions required about four months—e.g., from April

FIG 168—Showing a Sierran summer cabin in which relapsing fever was contracted Lower figure interior view of same cottage

29, when eggs were laid, to August 24, when eggs were laid by a female from the April 29 hatch of eggs.

The life cycle may be greatly prolonged in the absence of food because of the ability of these ticks to withstand starvation; thus larvae

may live as long as 95 days without food; unfed first-molt nymphs may live as long as 154 days; unfed second-stage nymphs may live as long as 79 days; third stage, as long as 109 days, and adults well over seven months. Adult ticks have been kept alive in pill boxes with occasional feedings for a period of over four years.

The mature female tick (Fig. 166) measures from 5 to 6 mm. in length by 3 to 4 mm. in width. The male resembles the female closely in general appearance but is slightly smaller. This species is described as ovoid, conically pointed anteriorly, anterior dorsal portion of hood visible from above, broadly rounded posteriorly; unengorged specimens a light sandy color with the black of the intestinal diverticulae visible through the integument of the dorsal surface; freshly engorged specimens a dull, deep garnet shade with a grayish sheen over body, anterior conical point whitish. The color changes to a grayish blue a few days after feeding Legs and hood pale yellow. In newly molted forms the body and legs are lighter but gradually assuming the light sandy appearance and the legs darkening correspondingly.

The eradication of the infection from summer cabins (Fig 168) known to be infested because of the origin of cases season after season is a difficult matter, primarily because of the nature of construction, which not only permits chipmunks to nest between the walls but prevents proper fumigation due to leakage. Driving out the rodents and then keeping them out by securely closing all crevices to prevent return is a good procedure, except that the ticks which are then deprived of their natural food will turn even more freely to the human occupants. No sprays are available that can be forced far enough into crevices to reach the concealed ticks by means of the usual hand equipment. Power spray equipment and an oil spray as heavy as the equipment can handle is recommended. The use of treated creosote as freely as circumstances will permit is also suggested.

Since the ticks behave as do bedbugs, bedsteads and cots should be liberally sprayed, heated or otherwise treated. Mattresses, bedding and sleeping bags and particularly equipment stored over winter must be treated as for bedbugs. Use of such equipment which has been stored over winter in cabins and has not been treated is a dangerous practice.

The first cost of rodent-proofing cabins to exclude chipmunks and other small rodents is neither difficult nor great, and is a practice that should be employed in all areas where tick-borne relapsing fever occurs Avoid soiling the fingers with the blood of chipmunks or squirrels.

Other members of the genus Ornithodoros.—Since the discovery that African relapsing fever is transmitted by *Ornithodoros moubata* (Murray), many other species of *Ornithodoros* have been found natu-

ially infected with spirochaetes infective to man; indeed it is believed that any species of this genus is capable of transmitting all strains of relapsing fever normally transmitted by ticks belonging to this genus, though the author and his students have been unable to transmit the California strain by means of *Ornithodoros coriaceus* Koch or *O. wheeleri* McIvor. *Ornithodoros savignyi* (Audouin) is an African, Arabian and Indian species which occurs in human habitations as well as in loose dry earth. It has been proved to be a vector of African relapsing fever by Brumpt, but is able to transmit the infection only as an adult and evidently does not transmit the infection to its offspring.

Ornithodoros talaje (Guérin-Méneville) is a South and Central American and Mexican species occurring also in Florida, Texas and Colorado, and has been collected in San Bernardino County, southern California and in Contra Costa County[68] It feeds on swine, cattle, horses, man and other mammals. It inflicts a very painful bite. It is the vector of relapsing fever in Panama, Venezuela and Colombia. Bates, Dunn and St John[69] proved this tick a vector of relapsing fever in Panama by human experimentation in 1921; in one instance the bites of a naturally infected tick resulted in infection. This species has been reported from New York by Matheson,[70] who remarks, "How this tick reached there (Ransomville, N Y.) can only be surmised. It probably maintained itself in the heated house and fed on the occupants or more probably on mice or rats or the domestic cat and dog, though none of these is listed as its normal host."

Ornithodoros venezuelensis Brumpt is a Central and South American species. It transmits relapsing fever in Colombia, Venezuela and Panama. Dunn[71] collected 4,880 ticks of this species in 68 homes in twenty villages, towns and cities in various parts of Colombia. Ticks infested with relapsing fever spirochaetes were present in nearly 28 per cent of the homes in which collections were made. The altitude mentioned for one of the localities was 2,700 feet, i e., a barracks at Muzo.

Ornithodoros erraticus Lucas occurs in Spain and northern Africa It is an important vector of relapsing fever in northern Africa. *O. papillipes* Birula [*O. tholozani* (Lab. et Megnin)] is a vector in Central Asia.[72] *O. normandi* Larrousse is a very small Tunisian species, reported to be a vector of relapsing fever.

Ornithodoros coriaceus Koch (Fig 191) is known as the Pajaroello or Pajahuelo in California. It is undoubtedly one of the most venomous species of ticks (see Chapter XXIII). *Ornithodoros pavimentosus* Neum. of Central Africa and Australia also inflicts a severe bite.

Matheson[73] has recently described three new species of *Ornithodoros* from bats, namely *O. dunni*, from the Little Bull Bat, *Dirias albiventor minor* (Osgood), captured in Panama City and Panama Canal Zone;

O. azteci from the bat, *Hemiderma perspicillatum aztecum* (Sauss), Panama Canal Zone; and *O. brodyi*, from the same host in caves.

Ornithodoros parkeri is described by Cooley [74] from ground squirrels (*Citellus* sp.), jack rabbits (*Lepus*) and the cottontail in Wyoming and Washington.

Ornithodoros wheeleri is a new species described from Merced County, California, by McIvor.[75] The natural host is unknown. Both of these species resemble *Ornithodoros turicata* (Dugès) very closely.

Spirochaetes of relapsing fever.—The causal organism of the louse-borne European relapsing fever was discovered by Obermeier in 1873 and named *Spirochaeta recurrentis* by Lebert. That of the louse-borne Asiatic relapsing fever was named *Spirochaeta carteri* by Manson in 1907, while the American louse-borne strain was called *Spirochaeta novyi* Schellac, 1907. The causal organism of tick-borne Central African relapsing fever was named *Spirochaeta duttoni* by Novy and Knapp in 1906. The South and Central American strain was called *Spirochaeta venezuelense* by Brumpt in 1921 and the Texas, U. S. A., strain was called *Spirochaeta turicatae* by Brumpt in 1933. Other strains such as *S. kochi* Novy, 1907, and *S. hispanica* Sadi de Buen, 1926, *S. persica* Dschunkowsky, 1912, have also been recognized as well as a number of others.

Fig. 169.—Spirochaetes of relapsing fever in a blood smear.

That these are probably all strains or local varieties of one widely distributed species, *Spirochaeta* (=*Treponema*) *recurrentis* Lebert is believed to be the case by various authors.

The spirochaetes of relapsing fever in man and rodents in California (Fig. 169) have been carefully studied by Miss M. Dorothy Beck.[76] She reports thirteen strains of spirochaetes resembling *Spirochaeta* (=*Treponema*) *recurrentis* from rodents in the field. Only chipmunks (*Eutamias* sp.) and tamarack squirrel or Sierra Nevada chickaree (*Sciurus douglasii albolimbatus* Allen) were found to harbor spirochaetes in the districts surveyed. She reports long periods of latency in mice, up to one hundred and fourteen days, also the spirochaetes of both human and animal origin show remarkable resistance to freezing, and remain viable in defibrinated sheep blood for at least 195 days. She concludes that the

rodent and human strains are identical in morphology and similar in susceptibility for laboratory animals. "These strains are undoubtedly the same since the rodent strains are directly transmissible to man."

Argas persicus (Oken) (*Argas miniatus* Koch, *Argas americanus* Packard), a cosmopolitan *fowl tick*, is one of the most important poultry parasites in existence (Fig. 170). In addition to "fowl tick," this pest is commonly called "adobe tick," "tampan" or "blue bug." In color it varies from a light reddish brown to a dark brown, depending on the stage of engorgement. In size the obovate, flattened adults average about 8 5 mm. long by 5.5 mm. wide in the female, and 6.5 mm. long by 4.5 mm wide in the male. When unengorged their thickness is about .75

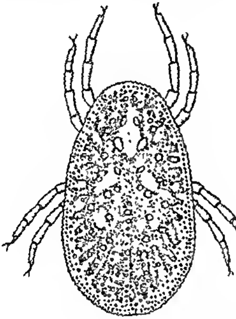

FIG. 170—The poultry tick, *Argas persicus*, dorsal view

mm. and when fully engorged may be nearly 3 mm. at the thickest part. The marginal border is always distinct even when the tick is engorged. The sexes are not easily distinguishable; the males are smaller, and though they may be as large as smaller female individuals, they taper slightly more anteriorly, i.e., are more obovate. The genital orifice of the male is "half-moon shaped," while in the female it is "slit-like" and situated farther forward, i.e., immediately behind the capitulum as in other argasines. The capitulum has four long hairs, two hypostomal, and one near the articulation of each palp, all directed forwards. The palpi are about twice as long as the hypostome, second article longest, the others equal in length. The hypostome has six or seven fine denticles on each

half distally, followed by stout teeth 2/2, the numbers increasing to 3/3, 4/4, 5/5, basally, the teeth decreasing in size, not attaining the external border nor extending beyond half the length of the hypostome (Nuttall).

Life history and habits.—The nymphs and adults of *Argas persicus* (Oken) are strikingly active at night, migrating long distances to find their host, and hiding in an inactive condition during the day. The writer has observed this pest in vast numbers hiding beneath the loose bark of the eucalyptus tree in California. Occasionally specimens are sent in with the inquiry, "Are they parasites of the tree or do they attack roosting chickens? The chickens seem to do very poorly, yet we find nothing on them." At night if one observes somewhat closely, one may see hordes of these ticks climbing up the sides of the chicken coop to the roosts and upon the fowls, filling up leisurely with blood and before daybreak departing for their hiding places. The females deposit their large reddish brown eggs in the crevices occupied during the day. The eggs are laid in masses of from 25 to 100 and over, and there are usually several layings, each preceded by a meal of blood, with a total of seven hundred eggs per female. Egg deposition takes place in almost any sort of receptacle in which the ticks may be kept for observation. Hatching takes place in from ten days to three or four weeks. The larvae (Fig. 171) are six-legged and very active, attacking a host apparently as readily by day as by night. Once attached the larvae feed for about five days, occasionally longer, remaining firmly attached during this time. When fully engorged they appear like little reddish globules, causing severe irritation. At the end of this feeding period the larvae detach themselves, having become rather flattened in the meantime, and then crawl away from the host, hiding in some convenient crevice near by. The larvae molt in about a week, when the fourth pair of legs appear and they are now in the first nymphal stage, appearing like miniature adults. Nocturnal feeding now takes place and in ten or twelve days another molt occurs and the second nymphal stage is reached. Again the tick attaches itself, being now able to engorge itself in about an hour; again, after the expiration of something over a week, a third molt takes place (there may even be a fourth molt) and then the adult stage is reached. The adults are able to engorge themselves in from 20 to 45 minutes. Under favorable conditions the adult stage is reached

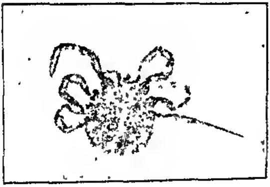

Fig. 171.—Larva of the poultry tick, *Argas persicus* × 30.

in about 30 days. Absence of hosts to feed upon may greatly prolong the life history.

Since eggs are deposited mainly during July in California, the adult stage may or may not be reached before the rainy season begins, and the overwintering stage may be in the second nymphal condition or as adults, appearing in pestiferous numbers early during the following summer. Hence there is ordinarily one generation of ticks per year under normal conditions. In the absence of a host this species can live more than two years without food.

This species will bite man Instances are recorded in which transient laborers occupying long-vacated but renovated poultry houses have been badly bitten by the poultry tick It might perhaps under certain circumstances become involved in the transmission of human spirochaetosis.

Damage done.—Each tick when engorging requires considerable blood to become replete, hence, when myriads of these parasites attack fowls great quantities of blood must be extracted. The writer has known of chickens being picked up under the roost in the morning with no apparent cause for death, and believes this to have been due directly to the work of ticks. Weakened and unthrifty condition of a flock may be traceable solely to ticks Poultry suffering from ticks have dull, ragged plumage, suffer from diarrhea, are weak and lay poorly. Turkeys are most likely to suffer.

Avian spirochaetosis.—A very fatal disease, known as "fowl spirochaetosis," is traceable to *Spirochoeta gallinarum* Blanchard (*Spirochaeta marchouxi* Nuttall), occurring in India, Australia, Brazil, Egypt and Persia, and is no doubt very widely distributed. The disease attacks chickens, geese, turkeys, guinea fowls and other birds. The symptoms are described as follows:

> "The disease begins with diarrhea, followed by loss of appetite, the birds appearing somnolent; the feathers being ruffled and the comb pale. The birds cease to perch, lie down with the head resting upon the ground and death takes place during a convulsive attack At times the disease runs a slower course, the legs become paralyzed, then the wings, and the bird grows thin and dies in eight to fifteen days. Recovery may take place, but it is rare after paralytic symptoms have appeared. At autopsy, during the acute period of the disease, the spleen appears much enlarged and the liver swollen with more or less fatty degeneration; at times the liver is dotted with focal necroses In chronic cases both these organs may appear atrophied. The blood is fluid and dark Spirochaetes are plentiful in the blood until shortly before death, and they disappear as recovery sets in" (Nuttall).

Argas persicus (Oken) was proved to be a vector of this spirochaete infection by Marchoux and Salimbeni, Balfour, Nuttall and others. These investigators have found that when this tick sucks blood from an infected fowl the spirochaetes multiply within the body of the same

when kept at from 30° to 35° C. and are capable of transmitting the disease; but when they are kept at from 15° to 20° C. they fail to transmit it. However, if the ticks are later kept at the higber temperature they become infective. The spirochaetes are transmitted by tbe bite and by fecal contamination; the ticks are said to be infective for six months or more. The infection is carried over from one generation of ticks to the next through the egg. The incubation period in the fowl is from four to nine days. Recovery from the disease is followed by immunity.

Seddon [77] reported several mild cases of avian spirochaetosis in Australia (N.S.W.) in 1926. He states that the mildness of the attack may be attributed to the fact that the cases had occurred during the winter when the cold weather would inhibit the activity of the ticks. The disease is now commonly found in the southern parts of New South Wales and in several other parts of Australia.

Combating the fowl tick.—Henhouse roosts should be painted thoroughly with kerosene or a solution of creosote and put in position with the ends in cups of crude oil or creosote or embedded in oil-soaked waste, or suspended by wires from the ceiling. Roost poles must be free from bark. All old nests and rubbish should be burned, and the interior, especially crevices, sprayed liberally with kerosene. Boiling water or steam may be used instead of kerosene. A repetition of the procedure once every five or six weeks during the tick season is recommended. The use of considerable crude oil or creosote oil in and about the houses is very desirable. Fowls should not be permitted to roost in trees, because of the hiding places afforded the ticks beneath the bark, particularly when loose.

If the henbouses can be made tigbt, fumigation with sulphur is useful, using about five pounds per 1,000 cubic feet of space.

For the treatment of fowls infested with larval ticks, an ointment of kerosene, lard and sulphur is advised.

Argas reflexus (Fabr.), commonly known as the "pigeon tick," differs from *A. persicus* (Oken) in that the body narrows rather suddenly toward the anterior end and that the thin margin is flexed upward. The capitulum bas "two long post-bypostomal hairs ventrally, directed forwards. Palps with articles sub-equal, the third the shortest, denticulated hairs dorsally. . . . Hypostome rounded terminally, some small denticles at the tip, followed by 2/2 atout teeth merging into 3/3 to 6/6 progressively smaller teeth" (Nuttall).

Other species of Argas are the following: *A. brumpti* Neumann, the largest known species of the genus, measuring 15–20 mm. in length by 10 mm. in width. It is known to attack man in Africa. *A. vespertilionis* (Latreille) occasionally attacks man in Africa. *A. mianensis* Brumpt

occurs in human habitations in Iran (Mianeh) where it is believed to be a vector of a spirochaete infection in man known as Mianeh fever.

The spinose ear tick, *Ornithodoros megnini* (Dugès) (Fig 172), occurs commonly in California and other subtropical parts of the United States. It is also found in Mexico, Central and South America, South Africa and India. It receives its name from the fact that the nymph is covered with numerous spines and in all stages the tick enters the ears of cattle, horses, mules and other domesticated animals and man. Rather large dark eggs are deposited by this species on the ground, where the seed ticks hatch. Under laboratory conditions at a temperature of about 21° C. the incubation period required is from 18 to 23 days. In the field newly emerged larvae crawl up weeds and other vegetation like the larvae of other ticks and gradually work their way to the shoulders, neck and head, and thence to the deeper inner folds of the ears of the host where they assume a peculiar sac-like form After molting in the ear the nymphs attach and remain attached for long periods of time when they detach, crawl out of the ear, drop to the ground and molt again, after which maturity is reached. Individual ticks may remain in the ear as long as 121 days in our tests. The writer has found that copulation takes place within a day or two after the final molt and that oviposition occurs in from 14 to 42 days after copulation with a maximum oviposition period of 155 days in the individuals observed, during which time as many as 562 eggs are laid. The longevity of unfed larvae at room temperature ranged from 19 to 63 days, with an average of 44 days.[75]

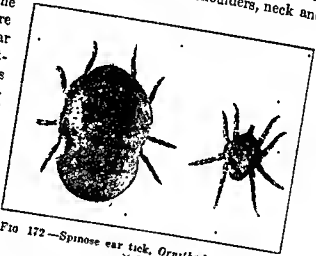

FIG 172—Spinose ear tick, *Ornithodoros megnini* × 3.5

Damage done.—The writer has received many complaints from various cattle-grazing districts in California relative to the "ear tick." Ears are occasionally sent in thoroughly infested with these pests in all stages It is commonly asserted that this tick is responsible for much deafness in domesticated animals, and it is also believed to be responsible for illness and even death, particularly in calves.

Treatment.—Owing to the position occupied by the ticks on the host, only local treatment is of any avail. A mixture of two parts of pine tar

to one part of cottonseed oil, injected with a warm metal syringe about one-half ounce in each ear (cattle and horses), is strongly recommended by Imes (U. S. Dept. of Agric., Bur. An. Ind. *Farmers' Bull. 980*). This mixture kills the ticks and affords protection against the invasion of others for about thirty days.

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CHAPTER XXII

MITES

CLASS ARACHNIDA, ORDER ACARINA

Characteristics.—In the mites, as in the ticks, the unsegmented abdomen is broadly joined to the cephalothorax with little or no evidence of separation. All species are minute, most of them being just about visible to the naked eye. The mites normally have four pairs of legs as have other arachnids, but possess only three pairs (exceptionally, less) as larvae. The mouth parts are quite varied but follow the general pattern of the ticks. The chelicerae in the species parasitic on vertebrates are adapted for piercing. One or more pairs of simple eyes are usually present The respiratory system is in most species similar to that of the ticks, i.e., tracheal, while others absorb oxygen through the general body surface which in these is quite soft. Nearly all species deposit eggs; however, there are a few which are ovoviviparous, among them, *Pediculoides ventricosus* (Newport). From the egg there emerges the hexapod larva, which usually soon molts and then presents its fourth pair of legs. The life history of many species is passed in less than four weeks, in some it is as short as eight days.

An infestation of mites is termed *acariasis*. Those species which burrow into the skin, producing channels and depositing therein their eggs, are said to cause *sarcoptic acariasis*, e.g., *Sarcoptes scabiei* var. *suis* Gerlach of swine mange; while those species which deposit their eggs at the base of the hairs of the host or on the skin and pile up scabs cause *psoroptic acariasis*, e.g., *Psoroptes communis* var. *ovis* (Hering) of sheep scab. Other forms of acariasis are recognized as indicated in this chapter.

Although Banks[1] recognizes 29 families of mites, only a few of these need be considered as affecting man or his domesticated animals. Students concerned with the study of mites will consult the published works of Ewing, particularly his "Manual of External Parasites."[2]

MANGE, OR ITCH MITES—SARCOPTIC ACARIASIS

Family Sarcoptidae

Characteristics.—All members of the family Sarcoptidae, commonly known as the itch mites, mange mites or scab mites, are very small (just

about visible to the naked eye), whitish, and somewhat hemispherical in form. Banks characterizes this family thus:

"The body is entire, and the surface transversely striated and provided with a few bristles, often short, stout and sharp pointed. The legs are short and stout, arranged in two groups. The anterior legs are usually larger than the others. The tarsi commonly terminate in a stout claw. There is generally a long pedicellate sucker, sometimes with a jointed pedicel The claw or sucker may be [illegible] vork [illegible] nent [illegible] peak [illegible] the third pair of legs very large and long, while the fourth pair is very small. Sometimes there are plate-like lobes at the tip of the male abdomen, and the tarsi may terminate differently in the two sexes."

The family Sarcoptidae includes a number of important genera, among them *Sarcoptes*, *Psoroptes*, *Notoedres*, *Chorioptes*, *Otodectes* and *Cnemidocoptes*, each producing a particular type of acariasis.

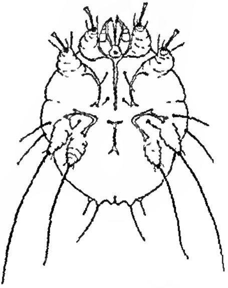


Fig 173 —*Sarcoptes scabiei.*

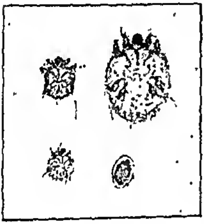
Mange or itch mites.—The mange or itch mites belong to the genus *Sarcoptes*, have very short legs, the posterior pair not extending beyond the margin of the nearly circular body; suckers are present on the first and second pair of legs. The sarcoptic mites burrow in the skin, where they produce definite burrows in which the females deposit their eggs.

The species of *Sarcoptes* inhabiting the skin of mammals are ordinarily termed varieties of *Sarcoptes scabiei* (Linn) (Fig. 173), the differences being very slight and many of them may interchange hosts, e.g., *Sarcoptes scabiei* var. *suis* Gerlach, parasitic on swine and on man, and when on the latter is known as *S. scabiei* var. *hominis* (Hering); *Sarcoptes scabiei* var. *equi* Gerlach of the horse is also parasitic on man. Given species of parasites, however, ordinarily exist only for a limited time on a different host species.

Human itch.—The itch mite attacking man is known as *Sarcoptes scabiei* var. *hominis* (Hering). The female measures 330 to 450μ in length and 250 to 350μ in breadth; the male is slightly more than half as large.

It attacks by preference the thin skin between the fingers, the bend of the knee and elbow, the penis, the breasts and shoulder blades, although any part of the body is subject to attack, producing an almost intolerable itching due to toxic secretions and excretions. The sinuous burrows which may reach 3 cm. in length[3] are made in the epidermis, and tiny vesicles and papules are formed on the surface. Scratching causes weeping and bleeding, and infection and spread of the mites are favored. Infestation is ordinarily secured by direct contact, such as hand shaking or exchange of clothing, towels, bedding, etc.

Life history of itch mite.—The female mites deposit their rather large oval eggs ($150 \times 100\mu$) at intervals in the tortuous tunnels which they have made in the epidermis. From 10 to 25 eggs are deposited by each individual during a period of about two weeks. The female, having deposited her complement of eggs, dies at the end of her burrow. The hexapod larvae hatch in three or four days. In this stage the area of infection is most rapidly increased. Maturity is reached in 10 to 12 days, during which time there are three molts.



(lower left), male (upper left); female (upper right). *Sarcoptes scabiei* var *suis*, the itch or mange mite of swine × 57.

Treatment for human itch.—Inasmuch as the mites are protected in their tunnels in the epidermis, the skin must be thoroughly softened by massage with green soap and hot water before a remedy is applied. Sulphur ointments, five per cent suspension of flowers of sulphur in lanolin, give very good results, if applied repeatedly at intervals of three or four days. Underclothing coming in contact with the parts affected should be boiled, steam sterilized or baked.

Swine mange.—Mange of swine is caused by *Sarcoptes scabiei* var. *suis* Gerlach (Fig. 174). Mange attacks the swine commonly about the top of the neck, shoulders, ears, withers and along the back to the root of the tail. A microscopical examination of deeper tissue from beneath scabs will usually reveal the mites. Comparatively few cases of swine mange have come to the writer's attention in California, even in localities where swine raising is carried on extensively, hence it seems that the disease is not as widespread as might be expected.

Suckling pigs and young shoats suffer most. The affected animals scratch and rub vigorously, which may, however, be due to lice, but if

the skin is cracked and thickly encrusted with heavy scabs, and the hair stands erect, an examination for scab mites should be made.

Infested animals should be isolated and immediately treated, and the quarters should be disinfected with a 10-per-cent creolin solution, 1 to 10 kerosene emulsion, 1 to 15 lime sulphur solution, or the like.

The life history and habits of the swine mange mite correspond in every respect with those of the itch mite of humans.

Treatment for swine mange.—In the treatment of swine mange it is necessary to apply external remedies, in addition to sanitary precautions to prevent spread and the reinfection of treated animals. Remedies are best applied in the form of solutions, for the reason that all parts of the animal's body are thus easily reached in the dipping process. Hand dressing or scrubbing or the application of ointments may be practiced where dipping is not practical, but even so all parts of the animal should be thoroughly treated.

Mayo,[4] of the Virginia Polytechnic Institute, recommends a "lime and sulphur" dip most highly. He uses eight pounds of fresh lime and 24 pounds of flowers of sulphur to 100 gallons of water, slaking the lime with sufficient water to form a thick paste, sifting in the sulphur and mixing with a hoe. This mixture is placed in a kettle with 25 to 30 gallons of water and boiled for one hour at least, two hours being better. Mayo suggests using the entire mass for swine, which must not, however, be done for sheep. The dip is used warm at a temperature of from 100° to 110° F. This temperature may be maintained by running a steam pipe along the bottom of the dipping vat.

Prepared "lime and sulphur" dips can be secured readily on the market, and are commonly used at the rate of one part of the solution to fifteen parts of water; however, care should be exercised to use the dip as directed, owing to variation in constituents. Coal-tar dips are also used extensively and give good results if used properly.

Dipping vats may be made of wood or concrete and are usually set in the ground at a slight elevation to insure drainage away from the vat. A convenient size for a vat is "ten feet long on top, eight feet long on the bottom, one foot wide on the bottom and two feet wide at the top. The end where the hogs enter should be perpendicular and the other end inclined, with cleats, so that the hogs can emerge after passing through. The entrance should be by a slide. For pigs and small shoats that can be easily handled, a barrel serves the purpose well; the pigs can be caught, plunged in the dip and held there the required time. Some successful swine raisers build cement bathing places or wallows for swine and keep these filled with a watery solution of some dip or disinfecting solution. If swine have wallowing holes filled with water, some of the good dips should be put in these frequently." The time to treat young pigs, and this

is important, is at weaning time. Dipping twice as for older animals is necessary, and if placed in uninfected quarters they ought to remain clean.

Mangy swine should be hand dressed with a stiff brush before dipping in order to loosen up scabs, and then kept in the dip long enough to permit the solution to soak through the scabs, certainly not less than two minutes. All the animals must be dipped a second time in eight or ten days, in order to destroy the mites which have hatched from the eggs which are not destroyed.

Mayo (1910, loc. cit.) recommends a disinfecting whitewash to be applied to pens, etc.: "Fresh lime, 25 pounds, flowers of sulphur, 15 pounds; mix the sulphur with a little water, to a paste, add 30 gallons of water and cook for an hour, then add water sufficient to make 50 gallons and apply with a spray pump, using a 'Bordeaux' nozzle."

Equine mange.—Sarcoptic acariasis in horses, mules and asses is caused by *Sarcoptes scabiei* var. *equi* Gerlach. This species is also transmissible to man and is said to be the chief cause of the itch of cavalrymen and others handling horses extensively. Infestation of humans is, however, only temporary.

The most reliable diagnostic character is the discovery of the mite, which is accomplished as in swine mange. The usual symptoms are first of all a strong tendency to rub some circumscribed part such as the head, root of the mane or tail, withers or back, due to an incessant itching. If a person scratches the affected parts, the animal moves its lips as though it were nibbling. The skin of these parts also shows an eruption of "fine conical papillae." The hair stands erect and bristly, much having dropped out, but totally bare spots where there are no isolated hairs apparently do not occur in mange, but do in ringworm according to Law.[5] The affected parts are at first scurfy, then become covered with yellowish scabs, which later exude matter due to the rubbing and inflammation, and finally there are formed scabs and crusts, often with deep crevices. During the first fourteen days the progress of the disease is usually slow, but by the sixth week the ravages of the disease become extensive and there is rapid progress.

The life history and habits of *Sarcoptes scabiei* var. *equi* Gerlach correspond in every respect with those of the other species already described.

Treatment for equine mange.—Before applying a local remedy for mange it is necessary to clip the entire animal, so as to disclose all points of attack which might otherwise be hidden by hair. The clipped hair must not be blown by the wind but should be burned. The parts affected are next thoroughly lathered and left for a short while to soften, after which warm water is applied and the scabs rubbed off as far as possible

with wisps of hay or straw and these also burned. The affected parts are now ready for a parasiticide, which should be applied by hand.

Many remedies may be obtained for mange, all of which have more or less virtue, but the writer has found that those containing sulphur are the most effective. The ordinary ...

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live ste ... one part to 500 of water. If the ... used its very poisonous properties must be considered. Brushes, scrapers, "rubbers," etc., should be boiled; harness should be rubbed thoroughly with a strong disinfectant.

Bovine mange.—Sarcoptic acariasis ... *Sarcoptes* ... (scal ... where the hair is short, as th ... around the base of the tail.

Canine mange.—The common mange of dogs is caused by *Sarcoptes scabiei* var. *canis* Gerlach, closely resemb... in the ... a ... elsewhere. Symptoms are m ... and horses.

Infected long-haired dogs should be clipped before treating. Law (Textbook of Veterinary Medicine, loc cit.) recommends the following treatment:

"The whole ... potash ... I ... 5 drops. This may be ap ... until a cure is established. Another very effective dressing and equally safe is sulphur, 1 oz.; carbonate of potash, ½ oz.; lard, 4 oz. For house dogs balsam of Peru or styrax ... or alcohol, 1 pint ... ing, which t ... alcohol 15 is very efficient." To ... acid and other poisons which may be licked off by the dog should not be used, unless a tight muzzle is provided.

Notoedric mange.—Mange of cats is caused by *Notoedres minor* var. *cati* (Hering) (*Sarcoptes minor* var. *felis* Gerlach), smaller and more circular than *Sarcoptes* but otherwise quite similar Notoedric mange of cats begins at the tips of the ears and gradually ... and head After ... ointments o ... potassium carbonate one part, and lar ... parts. *N. minor* var. *cuniculi* Gerlach causes a severe

attacks the lower parts of the legs of horses, particularly those with long hairs on the fetlocks. The infection is known as "aphis foot" in parts of Australia.[7] A mixture of one part carbolic acid to 15 to 20 parts of linseed oil, or equal parts of kerosene and linseed oil, is recommended as treatment. Several applications are needed to effect a cure.

Tail mange in cattle caused by *Chorioptes bovis* (Gerlach) is localized on the tail or legs and is uncommon. Foot mange in sheep is caused by *Chorioptes ovis* (Railliet).

SCAB MITES—PSOROPTIC ACARIASIS

Characteristics of psoroptic mites.—The psoroptic or scab mites belong to the family Sarcoptidae as do the itch and mange mites, hence

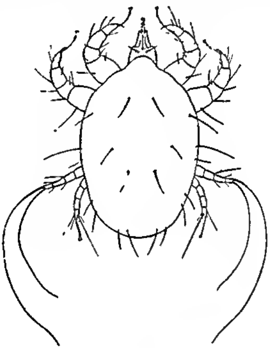

FIG. 177.—*Psoroptes communis.*

partake of the family characteristics. However, in the psoroptic mites the legs are long and slender, all four pairs extending beyond the margin of the body, which is elongate. The "pedicel of the suckers is jointed" and the "mandibles styliform, serrate near tip" and suited for piercing. The psoroptic mites do not burrow, as do the sarcoptic mites, but live at the base of the hairs of the host, piercing the skin, causing an exudate which partially hardens, forming scabs which pile up as a crust of loose humid matter. This condition is known as *scabies* or *scab*. Among the piled-up scabs the eggs are deposited. Owing to the loose condition of the scabs and the hardihood of the mites, this form of acariasis becomes quickly

and easily distributed from animal to animal by contact and by rubbing against fences, trees, and the like.

The commonest scab mites belong to the genus *Psoroptes* (Fig. 177) of which *Psoroptes communis* var. *ovis* (Hering) of the sheep is best known. Other varieties of this species infest cattle and horses mainly.

Ovine scabies (sheep scab).—*Psoroptes communis* var. *ovis* (Hering) is the causative organism of scabies in sheep. This is by far the most important species of scab mite. However, with the widespread use of dips, and rigid quarantine regulations, scabies in sheep is gradually being controlled.

The sheep scab mite is easily visible to the naked eye. The adult female measures about "one-fortieth" of an inch in length by "one-sixtieth" of an inch in breadth, and the male "one-fiftieth" by "one-eightieth" of an inch. As in all psoroptic species the mites are found on the surface of the body among the scabs at the base of the hairs The parts of the body most thickly covered with wool are chiefly affected.

Symptoms of sheep scab.—Scabies is first indicated by a slight "tagging" of the wool, the coat becomes rough, ragged and matted at the points affected. Tags of wool are torn away by the sheep or are left attached to rubbing posts and other objects against which the animal rubs. The sheep scratches vigorously and shows signs of intense itching. Law (loc. cit.) describes the symptoms of this infection thus:

> "The skin of the affected part is covered with yellowish papules of varying size, and a marked accumulation of scurf among the roots of the wool Later the affected skin swells uniformly, and the increasing exudation concretes into a massive scab enveloping the roots of the wool, so that as it increases layer by layer on its deeper surface, it lifts the fibers out of their follicles, detaching the wool and leaving extensive bare scabby patches The denuded surface shows all the variation of lesions shown in other mangy animals Papules, vesicles, pustules, scabs, cracks, excoriations, and even sloughs may appear at different points. Sometimes in clipped sheep the exudate forms a uniform, smooth, parchment-like crust covering the whole exposed area Around these bare patches the wool is encrusted at its roots, or shows a dark, dirty, scurfy layer composed of epidermic cells, yolk, dried exudate and the exuviae of the acarus. Beneath this the parasite is found in myriads The bare spots may show comparatively few "

Life history of the scab mite.—The female scab mite deposits an average of about 15 (maximum 30) eggs, one at a time, and the period of oviposition often lasts several days, when the female evidently dies. The eggs (Fig 178) are either attached to the wool near the skin or deposited directly upon the latter. The hexapod larvae hatch in from two to three days when next to the skin, but take longer (up to six or eight days) when on wool not close to the body, the first molt taking place in three or four days when the fourth pair of legs appears; a second and third molt take

place within the next four or five days. The males are said to molt but twice, and the female is fertilized *after* the second molt with a third molt before egg deposition. The length of time elapsing from egg to egg averages about nine days.

Treatment for sheep scab.—Internal remedies, such as sulphur, have been found to be unsuccessful by the U. S. Department of Agriculture. However, sulphur applied externally in the form of "lime and sulphur" dip has been used for many years as a successful remedy. Several kinds of dips with variations are commonly used against sheep scab, among

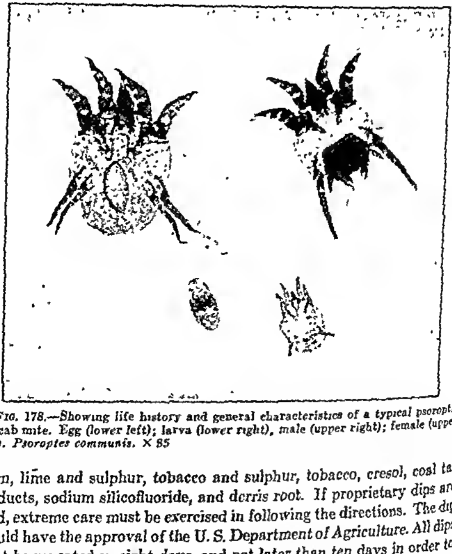

FIG. 178.—Showing life history and general characteristics of a typical psoroptic or scab mite. Egg (lower left); larva (lower right), male (upper right); female (upper left). *Psoroptes communis.* × 85

them, lime and sulphur, tobacco and sulphur, tobacco, cresol, coal tar products, sodium silicofluoride, and derris root. If proprietary dips are used, extreme care must be exercised in following the directions. The dip should have the approval of the U. S. Department of Agriculture. All dips must be repeated in eight days, and not later than ten days in order to destroy the mites newly hatched from eggs, since very few dips, except perhaps creosote dips, are injurious to the eggs.

Lime and sulphur dips.—Experience in many sheep-raising districts has proved that lime and sulphur dips are most efficient in the control of scab, if properly used. Damage to the wool, if dipping is done shortly

after shearing, is very slight indeed. The lime sulphur must test 0.18 to 0 19 per cent.

The dipping vat.—Dipping vats may be constructed either of wood or of concrete, should be about nine inches wide at the bottom, two feet six inches at the top, about five feet deep, and 35 to 40 feet in length The entrance end is built steep while the exit end has a gradual slant provided with cleats. The sheared sheep are driven into the receiving pen, the dip having been prepared in the meantime and warmed to 103° to 105° F. One after another the sheep are forced into the dip, in which they must be kept three minutes and the head drenched at least once while traveling toward the exit end of the vat From the vat the sheep emerge into dripping pens.

Bovine scabies.—Scabies in cattle is caused by *Psoroptes communis* var. *bovis* (Gerlach) and is comparatively common. The disease usually appears at the root of the tail, thighs, neck and withers and spreads rapidly to other parts of the body According to Imes [8] heavy losses may result from this disease.

Treatment for scabies in cattle is most successfully undertaken with tobacco-sulphur dips or lime and sulphur dips. The former is used as in sheep scab, while in the latter twelve pounds of unslaked lime and 24 pounds of flowers of sulphur to 100 gallons of water are used

The following general directions are given by the South Dakota Agricultural Experiment Station: [9]

"1 The temperature of the dipping vat should be constantly maintained at from 103° to 105° F

"2 Animals badly affected are preferably to be hand dressed by scrubbing the scabby areas with a stronger solution of the dip When lime and sulphur is used this has the effect of softening the firm scab, allowing the dip to penetrate

"3 Each animal should be held in the vat for two minutes, and completely immersed twice.

"4. All animals that have been in contact with the diseased ones should be regarded as infected and dipped.

"5 The dipping should be repeated in from ten to fourteen days to destroy the parasites that may have hatched out subsequently to the first dipping."

Auricular Mites—Otacariasis

Auricular mites.—A comparatively common affection of cats, dogs and foxes is known as *otacariasis* or parasitic *otitis* and is traceable to *Otodectes cynotis* (Hering) which resembles *Psoroptes* very closely. These mites belong to the family Sarcoptidae. The mites literally swarm in the ears of the host, causing much discomfort, tenderness of the ears, auricular catarrh, loss of appetite, wasting, torticollis, "fits," etc.

Cleansing the ears first with soapsuds and warm water, and then applying a sulphur ointment or a 10-per-cent solution of tincture of iodine

in glycerin, or a one-per-cent solution of carbolic acid in linseed oil is recommended. Banks recommends injecting olive oil containing one-tenth part of naphthol. The hutches or kennels must be thoroughly disinfected with a strong lime-and-sulphur solution or carbolic acid to prevent further contagion.

Follicle Mites—Follicular Mange

Family Demodicidae

Characteristics of follicle mites.—The Demodicidae include very minute (.3-.4 mm.) mites with an elongated transversely striated abdomen and four pairs of "stubby" three-jointed legs.

The follicle mite (*Demodex folliculorum* Simon) (Fig. 179) inhabits the hair follicles and sebaceous glands of man and other mammals "causing inflammation of the gland (comedoaes); their agglomeration in the meibomian glands (in man) sets up inflammation of the margins of the eyelids" (Max Braun). While the follicle mites may, under certain conditions, produce acne-like conditions, it is hardly probable that many cases of "blackhead" if any, may be traceable to these mites. They are nevertheless very common—said to occur in 50 per cent of mankind in all parts of the world.

Fig. 179.—A follicle mite. *Demodex folliculorum*. × 110.

In most animals the follicle mites are found in the region of the muzzle and the infection is known as *follicular mange*, manifested by a reddish raw appearance. *Demodex canis* Leydig parasitizes the dog; *D. cati* Megnin, the cat; *D. equi Railliet*, horses, and *Demodex bovis* Stiles has been recorded from hides of American cattle in which swellings about the size of a pea were formed on the skin of the shoulder and neck. In these swellings great numbers of the mites occur. The value of the hides is said to be lessened to a considerable degree *Demodex phylloides* Csokor inhabits the skin of swine both in the United States and Canada, producing white tubercles.

Owing to the fact that the follicle mites occur so deeply in the skin, treatment is made very difficult. Penetrating materials are necessary, [illegible] applications of [illegible] as [illegible] ar been effected, which is doubtful. The following treatment for [illegible] mange in dogs is said to be of value—wash the dog with soap and water, then cleanse thoroughly and empty the pustules, after which soak the parts affected (or dip the animal) for five minutes in 5 per cent formalin

or 2 per cent formaldehyde, following this with an application of sulphur ointment. Repeat the treatment every three or four days until four or five treatments are given. The use of ichthyol prepared with lard or lanolin in the proportions of one to seven is suggested by various authors. The chances for the cure of follicular mange are slight and valuable dogs should be placed under the care of a skilled veterinarian where facilities are available for the production and administration of auto-vaccines.

RAT MITES

Family Dermanyssidae

Tropical rat mite.—One of the most troublesome mites of man is the ropical rat mite, *Liponyssus bacoti* (Hirst) (Fig. 180). Several other ecies of rat mites of the same genus, particularly *L. nagayoi* Yamada, ve similar habits.

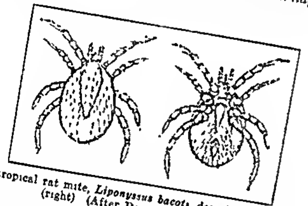

FIG 180—The tropical rat mite, *Liponyssus bacoti*, dorsal view (left), ventral view (right) (After Dove and Shelmire)

The tropical rat mite was first recorded from rats (*Rattus n norvegicus*) in Egypt by Hirst [10] and described as *Leiognathus bacoti*. This mite is now reported from many parts of the world as irritating to man; Bishopp [11] reported it from the southern United States in 1928 and it is now known to be widely distributed

"The bite is distinctly painful at the time the mouth parts are inserted A sharp itching pain is usually experienced Usually there is more or less irritation and itching at the site of the bite for several hours along with the development of a small haemorrhagic area" (Bishopp)

Shelmire and Dove [12] state that the eggs of this mite hatch in from four to six days. The newly hatched mites attach to the skin of the rats or mice for about two days, and when fully engorged drop from the host. Following molting the mites reattach There are four or five feedings and three or four molts before the parasites achieve maturity, according to these authors. The nymphs and adults are very active and readily leave

the nests of the hosts and travel freely for long distances and will readily attack man in restaurants, offices and other situations generally where rats have harborage near by.

Control of the tropical rat mite is essentially one of rat control. In the absence of food the mites perish in about two weeks, therefore if no other measures are taken, the pest will abate itself in about that time; however, with the elimination of the appropriate murine hosts they may become more annoying because of their enforced search for a blood meal. Along with rat control the author has recommended rubbing tables, desks, chairs, cabinets, and woodwork with a cloth moistened with kerosene. Bishopp recommends a mixture of anthracene oil, one part, and kerosene, two parts, for floors.

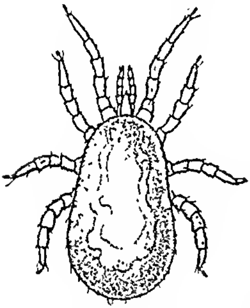

FIG 181.—The poultry mite, *Dermanyssus gallinae.*

Dove and Shelmire [13] (1932) report having experimentally transmitted the Texas strain of endemic typhus through bites of the tropical rat mite from guinea pig to guinea pig.

THE POULTRY MITE

Dermanyssus gallinae (De Geer), the poultry mite, also known as the roost mite, is the most important member of the Family Dermanyssidae. While this species is widely distributed in the United States another slightly larger species, *D. hirundinis* (Hermann), also troublesome to poultry is more localized in its distribution.

Habits and life history.—In size the mites vary from .6 to .7 mm. in length, are somewhat pear-shaped and are light gray when unengorged and from light to a dark red when engorged (Fig. 181).

During the daytime the mites remain hidden in the crevices of the henhouse, under the roosts, under boards, etc. In these hiding places the eggs are deposited. At night the pests swarm out from their hiding places and attack the fowls upon the roosts. Their attack is, however, not restricted altogether to the night, for swarms of them may be found on setting hens and laying hens during the day if these are nesting in darker situations.

Eggs are deposited in all sorts of crevices. The six-legged larvae hatch in two to six days, and after molting in about 24 hours without feeding take their first meal of blood as a first-stage nymph. After two more

molts if food is available the adult stage is reached. Under favorable conditions only ten days are necessary for the mite to pass through all its developmental stages. Wood,[14] who has studied this mite most carefully, states that under natural conditions in August this time would be reduced to at least eight and one-half days. Full growth is reached in from three to six weeks, depending on temperature. Some authors give the time for development at from ten days to two weeks. There are three or four molts before sexual maturity is reached.

Damage done.—The poultry mite is a serious pest in many parts of the world. The damage which this mite produces is very considerable and may be summarized as follows· Egg production is greatly reduced or entirely prevented; setting hens are often caused to leave their nests or perish; newly hatched chicks perish in great numbers in the presence of these mites; chickens lose flesh, are unthrifty, and are unprofitable for marketing; loss of blood and reduced vitality cause birds to be easily susceptible to disease. This species is known to be a vector of fowl spirochaetosis (see Chapter XXI). Inasmuch as the mites are seldom found on the bodies of the birds during the day, except in the first feeding period when they sometimes remain attached for a night and a day, or in dark nest boxes, control measures are directed most advantageously against the hiding places. A thorough clean-up of the premises to which the birds have access, together with the elimination of every useless article therein, such as boxes, coops, boards, etc., is the first step. Old nesting material should be burned and if the infestation is severe, roosts and nests should be dismantled to be replaced by construction that will facilitate future clean-ups. Methods must now be directed against the cracks and crevices of the floors, walls, and even the roof of the poultry house. In heavy infestations the mites sometimes migrate to the outside of the house when the inside is sprayed. They should be looked for along the cracks on the outside and, if present there, a spraying of the outside will be decidedly worth while. The most efficient manner of accomplishing this end is by the use of liquid insecticides applied preferably by "bucket" or "knapsack" spray pumps. A coarse spray is most effective and should be applied to each area from several different angles to insure penetration into all hiding places. Many of the existing sprays are efficient. Any of the dips used on domesticated animals made up in a slightly stronger solution than directed for the dipping of such animals will give fairly satisfactory results. The most satisfactory of all applications, however, are the wood preservers that have the coal-tar product anthracene oil as a base. These have the advantage of being effective over a long period and of soaking into the wood rapidly without leaving a greasy residue to soil the feet, feathers and eggs of the birds. They should be diluted about one-half with kerosene to facilitate spraying. One careful, thorough

treatment generally proves sufficient with this type of spray. *Crude oil* diluted sufficiently with kerosene to make it easily sprayed is efficient in killing the mites and is sufficiently durable but leaves the roosts, floors, etc., in an oily condition so that the flock must be excluded from the treated premises for some time in order to avoid soiling feathers and eggs. *Whitewash* containing three to five per cent of crude carbolic acid kills large numbers of mites but is not nearly so effective as anthracene oil or crude oil. Nicotine sulfate used on the roosts as for lice is effective in killing young mites feeding on the birds and in protecting roosting birds. Used as a spray at the rate of three tablespoonfuls per gallon of water to which is added one-half teaspoonful of baking soda it gives very satisfactory results if applied carefully and in drenching quantities

Prevention.—The common chicken mite is introduced into clean flocks in many cases in contaminated shipping coops. In some cases the introduction may be accomplished by a few young mites that are engorging for the first time on the introduced fowls. To overcome this possibility, newly acquired birds should be kept in special coops for two or three days before being placed in clean houses. These coops should then be destroyed or disinfected with boiling water or with one of the sprays suggested above Shipping coops from other poultry plants should not be left in or near clean houses, nor should second-hand equipment be introduced unless the proper precautions of disinfection are taken. Mites will live for from three to five months without food, a fact which should be considered when vacant buildings are to be occupied by clean flocks In cases where the control of the mite is impossible owing to the character of the quarters or lack of them, some relief is afforded by wrapping the ends and other points of contact of the roosts which have been painted thoroughly with crude oil, with rags soaked in the same substance to prevent the mites from gaining access to the fowls after they have roosted To make this procedure effective crowding should be discouraged and the back roosts should not be near enough to the wall to permit the movement of the mites to the plumage of the birds.

The tropical fowl mite, *Liponyssus bursa* (Berlese), is a fairly recent introduction into the United States (Wood)[15]. It is a common species on fowls in China, India, South America and Africa. Unlike *Dermanyssus gallinae* (DeGeer) above described, and which it resembles except for its smaller size, the tropical fowl mite remains on its host much of the time where it commonly lays masses of eggs in the fluff of the feathers, particularly below the vent and in the region of the tail. The entire life cycle requires but 8 to 12 days. Wood recommends dipping the fowls in a mixture of two ounces of sulphur, one ounce of soap and one gallon of water and treating the nests, floors, roosts, etc., with carbolineum. The application of nicotine sulfate to the roosts as suggested for lice is said to

be a good control if repeated three times at intervals of three days. The English sparrow serves as a favorable host for this species of mite and would no doubt be an effective agent in dissemination. *Liponyssus silviarum* (Canestrini and Fanzago), known as the northern fowl mite or feather mite, is similar in habits and may be similarly controlled.

Mites on canary birds require both the treatment of the birds and the cages, particularly the latter. The bird should be temporarily removed from the cage and dusted with fresh pyrethrum powder, while the cage and contents are being dipped in boiling water or baked in an oven.

Louse-like Mites

Family Tarsonemidae

Characteristics of Tarsonemidae.—This is a small family of soft-bodied mites having in the female a characteristic "prominent clavate organ of uncertain use" between the first and second pairs of legs. The third and fourth pairs of legs are separated from the first and second pairs by a long interspace. There is present a considerable sexual dimorphism in the several species. The piercing, sucking mouth parts are provided with slender needle-like stylets. Many of the species are predaceous or parasitic, while others suck the juices of certain plants.

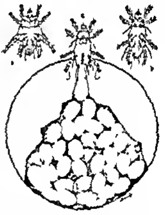

Fig 182 — *Pediculoides ventricosus* (a) male, (b) female; (c) gravid female, showing developing eggs (Redrawn after various authors.)

Pediculoides ventricosus (Newport) (Fig 182) is a widely distributed predaceous mite which attacks the larvae of a number of species of insects such as the Angoumois grain moth [*Sitotroga cerealella* (Oliv.)], the wheat joint-worm [*Harmolita grandis* (Riley)], the peach twig borer (*Anarsia lineatella* Zell.), the cotton-boll weevil (*Anthonomus grandis* Boh.), the bean and pea weevils [*Mylabris quadrimaculatus* (Fabr.) and *M. obtectus* (Say)], etc. It is therefore normally a beneficial mite, but unfortunately it also attacks man, producing a very disagreeable dermatitis commonly called "straw itch."

While the male mite is very tiny, just about visible to the naked eye, the female when pregnant becomes enormously swollen, measuring nearly a millimeter in length, the abdomen presenting a globular appearance, the cephalothorax and appendages barely visible.

Within the enlarged abdomen of the female may be found rather large

eggs which hatch internally, and the young mites develop to maturity within the body of the mother before being extruded. The number of young produced by the female is said to range from a few to nearly 300 The female mites are often fertilized within the body of the mother.

A number of epidemics of dermatitis have been traced to these mites, infection having been brought about by sleeping on straw mattresses or while laboring in grain fields at harvest time. The infection has been confounded with hives, scabies and even chicken pox and smallpox, and appears on the neck, chest, abdomen, back, arms, and legs, in fact the whole body may be involved and the itching is very intense. The eruption, which appears in 12 to 16 hours after the attack, is commonly accompanied with fever as high as 102° F.

According to Goldberger and Schamberg [16] the itching subsides under continuous exposure in from three to seven weeks. They also recommend treating the affection with an ointment of beta naphthol, sulphur, benzoate and lard.

To destroy mites in the straw of mattresses or in other situations, fumigation with sulphur or steaming or dry heat is recommended.

As to prevention Webster [17] suggests burning the grain stubble during the fall, winter or spring, also that threshing direct from the shock resulted in the control of the grain moth and consequently of the parasitic mites.

Flour and Meal Mites—Grocer's Itch

Family Tyroglyphidae

Characteristics of Tyroglyphidae.—This family includes a small group of very tiny mites, ordinarily about 0.5 mm. or less in length Several of the species attack grain, flour, meal, dried meat, hams, dried fruits, insect collections, etc. Their development is so rapid that there may be literally millions of them in a stored product in a few days.

The metamorphosis of this group involves a peculiar stage known as the *hypopus*, appearing after the larval and nymphal stages, very unlike either of these and very different from the adult. This stage is said to attach itself, non-parasitically, to flies and other insects, which serve as disseminators of the mites.

Persons handling stored products, cereals, flour, meal, etc., may be attacked temporarily by the mites, causing a severe dermatitis known as "grocer's itch," "copra itch," etc.

Tyroglyphus siro (Linn.) is the cheese mite, also found in grain and stored products; this mite causes a rash known as "vanillism" in vanilla pod handlers; *T.* (=*Aleurobius*) *farinae* (DeG.) is known as the flour mite and is common in flour mills and granaries; *T. americanus* Banks is

known as the cereal mite and is widespread and abundant on cereal products, seeds, stored prunes and other fruits; *Tyroglyphus longior* Gerv. attacks grains, cereals, dry seeds, etc., and causes "copra itch" among workers handling copra *T. farinae* (DeG.) and *T. longior* Gerv. have been reported from the urinary tract and *T. longior* Gerv. from the intestinal tract (intestinal acariasis[18])

Red Spiders

Family Tetranychidae

Characteristics of Tetranychidae.—To this family belong the "web-spinning mites," most commonly infesting vegetation and destructive to fruit trees and other plants. The term "red spiders" is ordinarily applied to the group. *Tetronychus bimaculatus* Harvey, the two-spotted mite, attacks many species of plants as does the common red spider, *T. telorius* (Linn.).

Persons employed in picking hops and harvesting almonds, etc., often complain of itching produced by the red spiders, but this soon disappears.

Pulmonary Acariasis

Family Dermanyssidae

Pulmonory acariasis of monkeys is traceable to mites of the genus *Pneumonyssus* which live in the lungs of the host, e g, *Pneumonyssus simicola* Banks *Halarochne attenuata* Banks occurs in the air passages of Alaskan seals and *Sternostomum rhinolethrum* Trouessart is said to produce catarrhal inflammation in fowls

Quill Mites

Family Cheyletidae

Syringophilus bipectinatus Heller, the quill mite of poultry, lives in the shafts of the primary wing feathers Rebrassier and Martin[19] report that this mite caused a peculiar molt; the loss of feathers extending over half of the body in most cases and in many instances the loss of all feathers. The birds were reported to be apparently in good physical condition. *S. columbae* Hirst is a quill mite of pigeons.

Air-sac Mites

Family Cytoleichidae

Cytoleichus nudus (Vizioli) is known as the air-sac mite of poultry because of its habitat in the air passages. *Laminosioptes cysticola*

(*Vizioli*) occurs in the subcutaneous tissue but is considered of no economic importance.

HARVEST MITES OR CHIGGERS

Family Trombidiidae

Characteristics.—The largest of all mites belong to the family Trombidiidae, some species being as long as half an inch. They are generally brightly colored, some of them being bright scarlet. The adults and nymphs are free living, some are plant feeders, others are predaceous; the larvae are parasitic. According to Banks (loc. cit.) they

"are recognized by the body being divided into two portions, the anterior (cephalothorax) bearing the two anterior pairs of legs, the palpi, mouth parts, and eyes; the posterior (abdomen) is much larger and bears the two posterior pairs of legs. The mandibles are chelate, at least there is a distinct jaw or curved spine-like process They are always red in color, some, however, being much darker than others. The body is covered with bristles or feathered hairs according to the species The palpi are five-jointed, quite prominent, often swollen in the middle, the penultimate joint ending in one or two claws, the last joint (often clavate) appearing as an appendage or 'thumb' to the preceding joint. The legs are seven-jointed, the tarsi terminate in two small claws. The legs are clothed in the same manner as the body. There are two eyes upon each side of the cephalothorax, quite frequently borne on the distinct pedicel."

The larvae of the subfamily Trombiculinae are called "chiggers" and have vertebrates as their natural hosts.

Chiggers attacking man are almost microscopic in size and because of their red color are often referred to as red bugs—*bête rouge* of Mexico, Central and South America. The common species in temperate and subtropical North America has been widely known as *Leptus irritans* Riley. This is the larva of *Trombicula irritans* (Riley) = *Trombicula thalzahuatl* (Murray) or according to Ewing [20] a member of a new genus *Eutrombicula* and now called *E. alfreddugesi* (Oudemans). The harvest mite of the British Isles is *Trombicula autumnalis* (Shaw).

The larvae (Fig 183) attach themselves to the skin by means of their hooked chelicerae and cause a severe dermatitis with intolerable itching. A burning sensation sets in within a few hours, increasing to an intolerable itching during the following thirty-six hours. Red blotches first appear and water blisters form in a day or two. In extreme infestations there may be a slight fever and sleep is difficult. Chigger infestations are usually acquired during late summer and autumn in temperate climates. Walking through weeds and shrubbery where the mites occur may result in infestations; penetration through clothing seems to be readily effected.

It is quite generally stated that chiggers burrow into the skin of their human hosts and there die, but Ewing [21] arrived at a different conclusion after a series of observations, viz.:

"To find out whether chiggers penetrate the skin or not, and also to observe their injury, resort was made to experimentation On July 15, 1919, the writer exposed the left calf and ankle to chigger attack. Daily observations were made on these chiggers, using low and high power lenses, for the next eight days. It was observed on the first day that the mites attached only by their mouth parts and in no way burrowed into the skin Observations on the second day showed no change; in fact, after once attaching to the skin by their mouth parts the larvae became quiescent and did not change their position until they dropped off. . . .

"Of the 26 numbered individuals that were observed and studied daily, 21 were attached to the smooth surface of the skin, while five were attached at the bases of hairs, each having the capitulum thrust into the mouth of the hair follicle Not a single one had penetrated a pore or hair follicle

"The species occurring in the northeastern part of the United States shows a tendency to attach at the mouth of hair follicles It may be that the larvae actually try to enter They are prevented, however, from doing so under normal conditions of the skin by the small diameter of the follicles themselves For this same reason it would be impossible for chiggers to enter the pores of the skin, unless the latter were greatly dilated as a result of some skin trouble In diameter the pores of the skin range from 20 to 50μ according to Piersol The width of an unengorged larva from either the western or eastern part of this country is approximately 150μ Thus it is seen that unless the pores were unusually dilated the mites could not enter if they would "

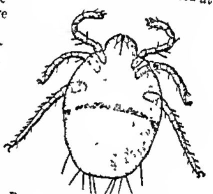

Fig 183 —Chigger mite or harvest mite, larva (Leptus) of Trombidium × 150

Life history.—The adult trombiculids are believed to feed on decaying vegetable matter in loose, moist surface soil, preferably humus where there is undisturbed wild vegetation such as wild blackberry brambles, etc. The eggs are deposited on the ground during the summer and autumn months. The hexapod larvae soon emerge and attach themselves to various hosts, such as rabbits, according to Ewing, and various species of snakes, such as black snakes and garter snakes, according to Miller.[22] Keay [23] reports a large number of hosts for *Trombicula autumnalis* (Shaw), including among others the dog, horse, vole, shrew, partridge, fowl and sparrow. When fully engorged the bodies of the bright red mites protrude beyond the margins of the scales. Throughout September, Miller states, the engorged larvae, which have been in this condition for

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CHAPTER XXIII

VENOMOUS AND URTICARIAL ARTHROPODS

Insect venoms.—Insect venoms, like other animal venoms, are toxic principles probably not greatly unlike the bacterial toxins, but about which we know comparatively little. Unlike many of the bacterial toxins which reach injurious amounts after a period of incubation subsequent to the introduction of the infection into the body, the animal venoms take effect almost instantly, i.e., as soon as introduced and without incubation.

The venoms act in one or more ways when introduced into the body: (1) they may act directly on the blood corpuscles (*haemolytic*); (2) they may act directly on the nervous system, producing shock or inhibiting reflexes (*neurotoxic*); (3) they may produce an infiltration and congestion of blood (*haemorrhagic*) often in the vicinity of the wound or deeper tissue, such as the mesenteries, etc A given specific venom may produce one or more of the above conditions.

It is a matter of common observation which has been verified by various investigators that repeated inoculation of minute or attenuated quantities of a venom may lead to a degree of immunity, so it is also with the venoms or poisons of bees, bedbugs, mosquitoes, fleas, conenoses, etc.

In the ants, bees and wasps (aculeate Hymenoptera) there are two poison-secreting glands, one of which produces *formic acid* and the other an *alkaline* fluid. The combination of the two agents in certain proportions is evidently necessary to produce the reaction of a bee sting.

The scorpion (an arachnid) secrets a large quantity of colorless acid-reacting liquid soluble in and heavier than water According to Calmette, less than 0.0005 gm. from *Buthus afer* Leach will kill a white mouse in about two hours.

How the venom is introduced.—Venoms of arthropods are introduced into the body of man in one of three ways: (1) by *contact*, e.g., with urticarial hairs of certain caterpillars, such as the brown-tail moth, *Nygmia phaeorrhoea* Don. [*Euproctis chrysorrhoea* (Linn.)], producing a condition similar to nettling, or with vesicating fluids of the blister beetles (Meloidae), particularly *Lytta vesicatoria* (Linn.), resulting in a *vesicular dermatitis*; (2) by the *bite* or thrust of a piercing proboscis, as in the conenoses (Reduviidae), or penetration of the chelicerae of

spiders; (3) by the *sting*, as in the bees or wasps (aculeate Hymenoptera) and the scorpion. The operation and structure of stings varies considerably, *notably in the* examples cited.

Stinging insects.—The stinging insects belong to the order Hymenoptera, suborder Aculeata, and are best known as the ants, bees, and wasps, in which the *females of all species* are provided with a specialized ovipositor known as a sting, more or less well developed for piercing the

FIG 185.— ... darts *b*, *b'*, ... sting palpi; *c*, ... ers; *f*, *f'*, semiluna ... arts; *i*, *i'*, points of ... vers rotate; *k*, *k'*, points of attachment for levers *f*, *f'*. × 17 5.

skin of higher animals or other insects The sting is used either as an organ of defense or offense, in the latter case often to procure food for the young. The venom apparatus of bees, wasps, hornets, bumblebees, etc., resemble one another in structure.

The principal aculeate Hymenoptera are divided into the following super-families: viz.: Formicoidea, the true *ants*; Sphecoidea, the *digger* wasps; Vespoidea, the true wasps; and Apoidea, the bees.

Morphology of bee sting.—Accepting the sting as a specialized ovipositor (genitalia), the worker bee (the underdeveloped female) may be used for this study. (Fig. 185.) The sting originates from the seventh and eighth segments and lies between the oviduct and the rectum above. The darts of the sting follow the ventral line of the abdomen aod are held in place by the sheath situated above, while the barbs of the darts point downward and outward. In a space above the sheath lie the fleshy palpi. The delicate attachment between the sting and the organs of the abdomen accounts for the ease with which the sting is torn from the abdomen when the barbs become embedded after the darts are thrust into the skin. The stiog can be easily extracted either by separating the segments of the abdomen from it by means of dissecting needles, or by squeezing the live bee between forceps, which causes it to protrude the sting. The sting can then be grasped with other forceps and drawn out. After extraction, the sting can be best examined when the parts are floated out in a few drops of glycerin. The sting may be divided into three parts, viz.: the piercing apparatus; the lateral plate and appendages; the poison sac and glands.

The piercing apparatus itself consists of three parts, one the so-called sheath, the other *two* lying within the sheath, and partially surrounded by it. In appearance the sheath is yellowish and translucent. The darts, which present concave surfaces to one another, are highly chitinous The distal one-third of the dart possesses a series of sharp barbs, whose shape has been aptly compared to the tip of a crochet needle. Cheshire states that each dart has from three to six barbs, other writers seem doubtful as to the number. Many darts have been carefully examined by the writer, but in no instance were less than *ten* barbs distinguished on the outer edge of each dart (Fig. 185). Several writers state that poison pores are to be found at the base of each dart, from which poison exudes. In this matter the writer agrees with Snodgrass, as he has failed to observe the exit of poison elsewhere than between the darts at their tip.

Proceeding upward on the dart from the tiny barbs, the darts are seen to form a letter Y as they lie within the sheath. The arms of the Y gradually bend laterally. Plates are attached to the upper edges of these laterally bent arms One of the most remarkable portions of the darts is the poison valve with which each is provided At the point of separation, the darts each present a delicate cup-shaped valve, whose closed portion is directed downward toward the tip of the sting This is formed of the same chitinous material which composes the darts, and each is free to move with the movement of the dart. In order to accommodate this enlargement of the darts, the sheath at this point expands to about five times its smallest diameter, which is at the tip of the sting. For at

least one-third of its length the sheath at this portion is expanded into a symmetrical oblong body providing ample room for the movement of the darts and valves within.

A curious structure, said by many writers to be found on the sheath, consists of two delicate, but strong, chitinous tracks or guide rails on which the darts, correspondingly grooved, fit and move back and forth. Since the sheath does not sufficiently surround the darts to direct their course, this guide-rail system which Carlet has observed, and which is accepted by other authors, probably explains why the darts move smoothly and accurately within the sheath.

The *lateral appendages* are of three kinds, viz.: semilunar, triangular and lateral, according to shape or position. Both the semilunar and triangular plates are attached to the bent ends of the Y-shaped darts. The triangular plates are attached to the arms of the darts almost at their extremities, while the semilunar ones are connected for about one-third of the distance from the ends of the arms. The apex of the triangle is attached to the extremity of the dart. The other two points point outward and downward, and serve as points of attachment for two elevated edges on the lateral plates which hang thus suspended. As they hang, half of their surface lies above and covers the dorsal surface of the semilunar plates just beneath them. Continuing in the same straight line with tho semilunar plates and attached at their extremity to them, lie the fleshy palpi covered with delicate hairs.

The third set of structures which completes the sting are the *venom sac and glands*. In order to understand these it is necessary to know that Hymenoptera are divided into two groups, those which kill their prey by stinging, and those which only paralyze it. The former are the more complicated, for they possess two poison glands; the acid gland, which opens directly into the great poison sac, the larger of the two, and the other, the alkaline gland, which is comparatively small and is situated at the base of the poison sac. It is the combination of the acid and alkaline fluids from the two glands that results in the death of the attacked insect, or that causes the extreme pain and resulting reactions in humans.

The formic acid gland alone is found in those Hymenoptera which only paralyze their prey by their sting. This fact has led various observers to make chemical tests of both the formic acid and alkaline substance. The result, according to Carlet and others, has been to show that neither substance by itself is effective except to paralyze, but when combined the substances have deadly effects upon other insects. Carlet's experiments to prove this were made upon houseflies and blowflies by injecting each substance singly and then introducing both into the body of a fly. The results are entirely convincing.

Operation of the sting.—The sting was observed in operation by confining the bee on its back and then prodding it until its sting was angrily thrust in and out. This process showed three things, viz.: that the sharp-pointed sheath always appeared first when the thrust was made; second, that the darts inside the sheath worked back and forth alternately, and quite independently of the sheath or of one another; third, that the poison exuded in droplets from the tip of the sting between the darts Cheshire (Bees and Bee-Keeping, London, 1886) states that

"The sheath has three uses: first, to open the wound, second, to act as an intermediate conduit for the poison; and third, to hold in accurate position the long-barbed darts. The sheath does not inclose the darts as a scabbard, but is cleft down the side which is below, when the sting points backward The darts, as soon as their ugly barbs establish a hold, first one and then another drive back and forth by successive blows These in turn are followed by the sheath, when the darts again plunge more deeply, until the murderous little tool is buried to the hilt. But these movements are the result of a muscular apparatus yet to be examined The dovetail guide-rails of the sheath are continued far above its bulbous portion, and along with these the darts are also prolonged upward, still held to the guides by the grooved arrangement; but both guides and darts, in the upper part of their length, curve from each other like the arms of the Y, before mentioned, to points C, C' (Fig. 185) where the darts make attachment to two levers (i, i'). The levers, or plates, as they are called (Kl and $K'l''$), are provided with broad muscles, which terminate by attachment to the lower segments of the abdomen. These, by contraction, revolve the levers aforesaid round the points f, f', so that without relative movement of rod and groove, the points c, c' approach each other The arms of the Y straighten and shorten, so that the sheath and darts are driven from their hiding place together and the thrust is made by which the sheath produces its incision and fixture The sides being symmetrical, we may, for simplicity's sake, concentrate our attention on one, say the left in the figure. A muscular contraction of a broad strap joining K and D (the dart protractor) now revolves k on l, so that a is raised, by which clearly c is made to approach d, that is, the dart it sent forward, so that the barbs extend beyond the sheath and deepen the puncture The other dart, and then the sheath, follow, in a sequence already explained, and which G is intended to make intelligible, representing the entrance of the sheath, b the advance of the barbs, and c the sheath in its second position The barb retractor muscle is attached to the outer side of i, and by it a is depressed and the barbs lifted These movements, following one another with remarkable rapidity, are entirely reflex, and may be continued long after the sting has been torn, as is usual, from the insect. By taking a bee under the microscope and forcing the sting into action, the sting movement will be seen to be kept up by continued impulses from the fifth abdominal ganglion and its multitudinous nerves, which penetrate every part of the sting mechanism and may be traced even into the darts These facts will show why an abdomen separated many hours may be able to sting severely, as I have more than once experienced"

Reaction to bee stings.—As has already been pointed out, the sting of bees can only be venomous when the products of the "acid" gland and "alkaline" gland combine at the moment when the insect is in the act of

species of pugnacious nature. Because of their number an attack may result seriously. Among the more formidable species are: (1) The California or Mexican fire ant, *Solenopsis xyloni* var. *maniosa* Wheeler, the workers of which have a yellowish red head and a black thorax and abdomen. They measure from 1.6 to 5.8 mm. in length. (2) The Texan harvester or agricultural ant, *Pogonomyrmex barbatus* (F. Smith) in which the head, thorax and legs are black and the abdomen red; the workers reach from 7 to 9 mm. in length; (3) the California harvester ant, *Pogonomyrmex californicus* (Buckley), body light rusty red, legs somewhat more yellowish. These ants will readily attack humans and smaller animals. Hog raisers in the Imperial Valley, California, report many young pigs killed by ants, particularly by the stings of *P. californicus* (Buckley). It is a matter of common observation to see a small pig walk leisurely upon an ant mound and suddenly begin to kick and squeal, due to the terrific attack of the myriads of ants rushing forth from the nest. The animals commonly topple over with legs outstretched and death may result.

Ants belonging to the subfamily Ponerinae also have well-developed stings and a potent venom. This is apparently particularly true of the Central and South American species, *Paraponera clavata* (Fabr.), which is common in high tropical rain forests. Weber [1] states that the ants of this species boil out of their nests in large numbers when disturbed and rush for the intruder. He states that the workers are fully an inch in length and blackish brown in color. The ant is greatly dreaded by the natives Weber describes the effects of a sting which he suffered.

For the control of the fire ant, Mallis [2] recommends the use of a mixture of one part of carbon bisulfide and three parts of carbon tetrachloride injected into the nest openings by means of an oil can with an eight-inch curve-tip spout. A few drops of the liquid in each opening are sufficient. After treatment the openings must be covered. A large measure of control may be effected by applying kerosene to the nests, using a funnel or hollow rod to reach the deeper parts; potassium cyanide in liquid form may also be used, but great care must be exercised both in its preparation and application owing to its very poisonous nature.

Mutillid wasps.—Among the less known stinging insects are the mutillid wasps belonging to the family Mutillidae (Order Hymenoptera). Members of this family are commonly known as velvet ants, woolly ants, cow killers, mule killers, etc. (Fig. 187.) The mutillids are covered with a velvety pubescence; many are brightly colored with orange or red or yellow. The females are apterous, good runners and possess a potent sting. They are parasites of bees and other wasps. There are very many species, some of the commoner forms measuring from $\frac{1}{2}$ to 1 inch in length. Our knowledge concerning these interesting

insects has been greatly advanced by Mickel.[3] A very common species in the central states of the United States is *Sphaerophthalma occidentalis* (Linn.), a black species with a scarlet band. This species is very common on the beach sands of Lake Erie, causing barefoot bathers much distress.

Stinging Epyris.—In 1927 von Geldern[4] reported a tiny wasp from Yolo County, California, identified as belonging to the genus Epyris which inflicted a severe sting.

"The wasps appear in fairly great numbers in the fall after a warm spell and invade the house where they get into the bedding and clothing, and sting when brushed or crushed by clothing or sheets against the skin . The sting is distinctly felt as a fairly sharp prick, decidedly less intense than a bee sting In the oldest and youngest child no further manifestations occur, but in the parents and second child a decided systemic disturbance follows A few minutes after being stung, there is felt a numbness, often at the site of the sting, but at other times beginning at the finger tips It remains localized for a few minutes and then gradually spreads and involves the entire body. In the mother there is an intense itching [illegible]

uterine cramps in the mother The diarrhoea and cramps last for about ten minutes The mother, who is an asthmatic, experiences no respiratory difficulty, but with the father, who has never had an attack of asthma, wheezing occurs occasionally Accompanying these symptoms there is marked prostration, weakness and sweating The duration of the attack is about half an hour. The second child becomes drowsy and is awakened with difficulty and wheezing occurs He also recovers in about the same time as the parents"

Fig 187—A velvet ant, Mutillidae, also known as a "cow killer" × 2 2

Essig[5] in 1932 reported a number of instances of *Epyris* stings all from the same county in California as were the cases reported by von Geldern The species of wasp was identified as *Epyris californicus* (Ashmead) belonging to the proctotrupid family Bethylidae. It measures barely over 5 mm. in length and is black in color. Essig states, "concerning the life history and habits of this particular species, beyond its propensity for stinging, absolutely nothing is known."

Biting (piercing) insects

Insects that pierce the skin with their mouth parts are usually normally bloodsuckers and the act of biting or piercing is simply a part of the act of food-getting. There are noteworthy exceptions as later

explained. The pain caused by the mechanical insertion of mouth parts would no doubt in most instances be relatively benign, particularly if only one or very few insects were concerned in the attack; however, in perhaps every instance a venom of salivary origin is introduced. These venoms apparently differ among the various species as evidenced by the resulting reactions, local and systemic, which are generally specific enough so that one who is experienced may be able to determine the cause, i.e., whether the offender was a bedbug, a flea, a mosquito, or a black fly (simuliid).

To understand the operation of the bloodsucking mechanism of the various offending insects one should consult the chapter on mouth parts and the other chapters appropriate to this subject. The student will profit much by a careful study of "Zoonosen der Haut in warmeren Ländern" by Martini [6] (1932). In general the reactions are the result of either *mechanical* or *chemical* (venomous) processes.

The variety of effects caused by the bites of bedbugs (*Cimex lectularius* Linn.) indicates that there is a wide range of human tolerance. Some individuals apparently suffer no ill effect from numerous attacks, not even the usual swelling at the site of the bite; others react violently to even one bite. These differences in tolerance to a given species are not fully understood. Martini remarks that doubtless allergic processes play a rôle in the manifestation of the reaction in different persons to insect bites. He further points out that dog fleas transfer easily to humans, and in some localities this species, *Ctenocephalides canis* (Curt.), is more abundant on humans than on dogs. *Xenopsylla cheopis* (Roth), the oriental rat flea, transfers easily to humans, while the European rat flea, *Nosopsyllus fasciatus* (Bosc), does not transfer quite so readily. *Pulex irritans* Linn., the human flea, is conspicuously common on swine

To what extent immunity plays a part in tolerance to insect bites is perhaps debatable; it is generally believed that natives suffer little or no inconvenience from bites of endemic species, e g., fleas, while transients or new settlers generally suffer greatly. This situation has stimulated investigation into the possibility of developing vaccines to hasten immunity to flea bites.

Insects that cause a very painful bite such as the stable fly, *Stomoxys calcitrans* (Linn.), and most salt marsh mosquitoes, e.g., *Aedes dorsalis* (Meig.), are not potent vectors of pathogens, while species with benign bites, such as *Anopheles maculipennis* (Meig.), are commonly vectors. May it not be that in order to become a successful vector of disease, the arthropod must first modify the severity of its bite!

Conenoses or kissing bugs, belonging to the family Reduviidae (see Chapter VIII), are most commonly concerned in the more painful "bites" inflicted by insects. Their mouth parts (see Chapter VI) are well

adapted for piercing the skin of the host. The reduviids are essentially predaceous, attacking many species of insects, particularly soft-bodied forms from which they suck the body fluids Attack upon humans is made principally, if not wholly, in self-defense. Persons picking up boards, sticks or stones, etc., may accidentally also pick up one of these insects, or in plucking a leaf or flower from a tree or other plant the fingers may close upon the insect as well, with the result that a very painful bite is almost invariably inflicted.

The principal offenders are about 18 to 20 mm. in length and all bear a general resemblance to the illustration (Figs 42 and 43.) Among the important species in their relation to human comfort are the following: *Reduvius personatus* (Linn.), known as the "kissing bug"; *Triatoma sanguisuga* (Lec), the "bloodsucking conenose" or "big bedbug"; *Triatoma protracta* (Uhler), the "China bedbug"; and *Rasahus biguttatus* (Say), the "two-spotted corsair "

The symptoms produced by *Triatoma protracta* (Uhler), the usual offender in California, are described as follows: "In a few minutes after a bite the patient develops nausea, flushed face, palpitation of the heart, rapid breathing, rapid pulse, followed by profuse urticaria all over the body. The symptoms vary with individuals in their intensity."

The symptoms described for *Rasahus biguttatus* (Say) are as follows·

"Next day the injured part shows a local cellulitis with a central spot; around this spot there frequently appears a bulbous vesicle about the size of a

Biting water bugs.—The order Hemiptera (see Chapter VIII) contains a number of families of aquatic forms several of which include biting species; among these are the families Belostomatidae and Notonectidae.

The giant water bugs *Lethocerus* (formerly *Belostoma*) and *Benacus* belonging to the family Belostomatidae are among the largest of the family of bugs, measuring 2½ inches (6.5 cm) in length and possessing formidable beaks. They feed on other aquatic insects, also young frogs, fish, etc., and since they are winged and readily attracted to lights, they are commonly known as electric light bugs They have been known to attack birds. Ewing[36] describes the effect of the bite as follows· at 9.30 A.M. a giant water bug *Benacus griseus* (Say) was allowed to bite the back of the right index finger. The beak was left inserted for a few seconds.

"Immediately a burning sensation followed Two minutes later the same bug was allowed to puncture the back of the left index finger for several seconds.

A burning sensation was produced. Soon some swelling was noted, and a reddened area developed about the point of the puncture. Pain continued but diminished during the forenoon and by noon the reddened area had become reduced. By 1:30 P.M. a small red spot was all that was left at the puncture. . . . When *Benacus griseus* bites it emits a milky fluid from the tip of the beak, and the beak adheres to the skin after penetration, so that the skin is pulled up when the beak is withdrawn."

Lethocerus americanus (Leidy), another species of giant water bug, may also inflict a severe bite with effects that may last for several days.

Back swimmers belonging to the family Notonectidae may also inflict a painful bite. These predaceous bugs swim on their backs, hence the common name back swimmers. The bite is nearly as severe as a bee sting.

Bloodsucking phytophagous bugs.—Numerous instances of bloodsucking among phytophagous Hemiptera have been reported. Much information concerning these cases has been assembled by Usinger (1934, loc. cit.) and Myers [7] (1929).

Among the species exhibiting this bloodsucking behavior are members of the following families: Membracidae, such as *Ceresa bubalus* (Fabr.); Cicadellidae, such as *Eutettix tenellus* (Bak.), *Erythroneura comes* (Say); Miridae, such as *Irbisia solani* (Heid.), *Sopidea marginata* Uhler; Coreidae, *Leptocoris trivittatus* (Say).

Usinger remarks that the change from the sucking of plant juices to bloodsucking at first appears to be very great. "However, upon comparison of the chemical constituents, it is found that in general the same elements are found in plants as in blood and often in very similar combinations although in very different proportions."

Thrips biting man.—Thrips (Order Thysanoptera) are minute plant-feeding (sapsucking) insects (see Chapter VI for description of mouth parts); however, there have been numerous reports of their attacking man and their ability to suck blood. Bailey [8] states that while working on experimental plots he experienced bites from the onion thrips, *Thrips tabaci* Lind. He felt slight pricks on the arms, face and neck, both when perspiring and when not. He observed that the larvae (second instar) were more prone to bite than the adults and that the alimentary canal took on a reddish brown appearance after feeding. Small pinkish dots appeared on the skin which disappeared in one to two days. There was no swelling but a slight itching sensation. He had similar experiences with the pear thrips, *Taeniothrips inconsequens* (Uzel).

Several other species of thrips have been reported in a similar connection, e.g., *Heliothrips indicus* Bagnall, a cotton pest of the Sudan; *Thrips imaginis* Bagnall, reported for Australia; *Limothrips cerealium* Haliday, for Germany; *Gynaikothrips uzeli* Zimmerman, for Algiers; and other species. It would appear that many species of thrips are thus involved and that this behavior is not restricted to a particular species.

Urticarial hairs.—The caterpillars of many species of Lepidoptera, (at least 8 families) possess urticating hairs. Among the families which have urticarial larvae are (1) the Saturnidae of which the genus *Hemileuca* is especially offensive. *Hemileuca oliviae* Cockerell, the range caterpillar, is reported to be a menace to cattlemen in New Mexico.[9] A rash known as the "brown-tail rash" is traceable to the caterpillar of the brown-tail moth (*Nygmia phaeorrhoea* Don.), a common and very destructive shade tree pest in Europe and in America, especially New England. When the caterpillars of this species molt, myriads of tiny barbed hairs are shed with the skin. The cocoons of the pupated caterpillars as well as the adult moths possess these hairs. These hairs are blown about by the wind and coming in contact with the skin of the neck, face, hands, or other exposed parts of the body produce a very severe dermatitis. The hairs are hollow and it has been shown by Tyzzer [10] that they contain a definite poisonous principle which is injected into the circulation by the sharp-pointed hair in contact with the skin, thus producing the rash. Ingestion of the hairs by swallowing or inhaling in breathing may cause serious internal disturbances.

Bishopp [11] describes the symptoms produced by contact with the "puss" caterpillar (*Megalopyge opercularis* S. & A.) as follows:

"Almost immediately after any portion of the body comes in contact with one of these caterpillars an intense burning pain is felt, described by some as similar to a severe nettle sting. This usually becomes worse accompanied by

s

y

spreading of the inflammatory area for several inches and often accompanied by general swelling of the portion of the body stung. Stings on the wrist have been followed by a swelling of the entire arm to almost double its normal size. A feeling of numbness which almost assumes the characteristics of paralysis accompanies the swelling. This is usually confined to the member attacked but may be generalized. Apparently stings on the neck are even worse, as the writer has one record of a man who was stung severely on the neck and completely

alytic symp-

The stings

considerable

two and are

accompanied by nausea, especially during the first few hours. Usually within two or three hours after a sting, the reddened pimple-like swellings at the site assume the appearance of small vesicles or blisters. These usually persist for a few hours and then apparently harden through absorption

ened area

of attack

paralytic symptoms usually subside with the pain, but the local lesions often persist for several days."

Students concerned with the subject of urticarial hairs will need to consult Weidner's [12] (1936) work which includes a comprehensive bibliography on the poisonous hairs. Weidner lists the following families of Lepidoptera which include caterpillars with hairs causing skin irritations, namely, Morphidae, *Morpho hercules* Dalm.; Arctiidae, *Lithosia caniola* Hbn., *L. griseola* Hbn.; Lymantriidae, *Nygmia phaeorrhoea* Don. [*Euproctis chrysorrhoea* (L.)], *Porthesia similis* Fuessly, and several others; Thaumetopoeidae, *Thaumetopoea pinivora* Tr., *Anaphe infracta* Wlsgh., and others; Lasiocampidae, *Macrothylacia rubi* (L.), *Dendrolimus pini* (L.), *Lasiocampa quercus* (L.), and others; *Noctuidae*, a few species occasionally cause irritation; Nymphalidae, larval hairs may pierce the skin, e.g., *Vanessa io* (L.) and *Hamadryas antiopa* (L.) (mourning cloak); Saturnidae, *Automeris io* (Fabr.) (Io moth), *Hemileuca maia* Drury (buck moth), and others; Megalopygidae, *Megalopyge crispata* Pack. (flannel moth), and others; Limacodidae, *Sibine stimulea* Clem. (the saddle-back caterpillar), and others.

Blister beetles.—Blister beetles belong to the family Meloidae (Cantharidae) (Order Coleoptera) and are so designated because of their vesicating properties, i.e., the application of the pulverized bodies or even the simple contact of many species produces a blistering of the skin.

The Meloidae (Cantharidae) are described by Comstock:

> "The blister beetles are of medium or large size. The body is comparatively soft; the head is broad, vertical and abruptly narrowed into a neck; the prothorax is narrower than the wing covers, which are soft and flexible; the legs are long and slender; the hind tarsi are four-jointed, and the fore and middle tarsi are five-jointed"

The blister beetles deposit their eggs on the ground, the larvae are active and feed, it is said, in some species on the eggs of locusts and solitary bees; others are predaceous. They undergo a number of changes not usual to insects, their development being termed hypermetamorphosis. The adults are vegetable-feeding.

Spanish fly.—The Spanish fly, *Lytta vesicatoria* (Linn.), is a European species of beetle found most abundantly during the early summer in Spain, southern France and other parts of Europe. It is golden green or bluish in color, ranges from one-half to three-quarters of an inch in length and makes its appearance quite suddenly in early summer, when it may be collected by the hundreds, clinging principally to such vegetation as the ash, privet and lilac. The peculiar hypermetamorphosis of these insects and the subterranean predaceous larval habits give to them some obscurity during their early development and the sudden appearance and equally sudden disappearance, owing to short adult life, gave rise to the belief that they were migrating forms.

The collection and preparation of the beetles for medicinal purposes provides an occupation for many persons for a brief period. Collecting and preparing the insects requires special precautions owing to their vesicating properties. The best quality of cantharidin produced from the pulverized beetles is the result of special care in the drying, which must be gradual. Cantharidin is an important local irritant used in medical practice. (See Chapter XXIV.)

Other blister beetles causing severe seasonal vesicular dermatitis in Africa belong to the following species, *Mylabris nubica* de Marseul, *Epicauta tomentosa* Maeklin, *Epicauta sapphirina* Maeklin, according to Chalmers and King [13]

Paederus crebripunctatus Epp. (Family Meloidae) is reported to be a severe vesicating beetle of East Africa [14] affecting Europeans and Africans similarly, although not severe on habitually exposed parts of the body of the latter. The term "Nairobi eye" applies to the conjunctivitis caused when the juices of crushed beetles are rubbed into the eye. The active principle is cantharidin. Roberts and Tonking (loc. cit.) recommend a cold compress of saturated solution of magnesium sulfate.

At least two species, *Sessinia collaris* (Sharp) and *Sessinia decolor* Fairm., belonging to the family Oedomeridae, cause severe blistering on some of the mid-Pacific Islands where they are called coconut beetles.[15] These beetles fairly swarm about the newly opened male flowers of the coconut where they feed on pollen. They are readily attracted by light. Coming in contact with one of these beetles causes a sharp momentary pain, like a burn from hot oil, but the large blister which forms in a few hours causes little pain.

Spiders

Class Arachnida—Order Araneida (Araneae)

General characteristics.—Spiders are arachnids in which the prosoma is uniform, bearing not more than eight eyes, and joined to the opisthosoma by a pedicle. The opisthosoma is usually unsegmented, and bears not more than four, usually three, pairs of spinnerets. There is no telson. The chelicerae are two-segmented, moderately large and unchelate, and contain a poison-gland. The pedipalps are six-segmented, leg-like and tactile in function. The legs consist of seven segments; the tarsi with two or three claws. Respiration is by lung-books or tracheae or, normally, both. The pedipalps of the male are modified as intromittent organs. (Savory, The Arachnida, Edward Arnold & Co., London, 1935) (Figs. 18 and 19.)

Though spiders are universally feared, no doubt because of their ability to kill insects by introducing a venom with the bite, it is never-

theless true that out of the more than two thousand genera in more than thirty families only a very few species are actually dangerous to man

Tarantulas.—The term *tarantula* was first applied to a European species, *Lycosa tarantula* (Linn.), which is a member of the family Lycosidae (wolf spiders).

To the bite of *Lycosa tarantula* (Linn.) is referred the hysterical disease known as *tarantism* said to have been common in southern Europe in the Middle Ages.

The following account of *tarantism* is taken from the Cambridge Natural History, Vol. IV, p. 361:

"The bite of the spider was supposed to induce a species of madness which found its expression—and its cure—in frantic and extravagant contortions of the body. If the dance was not sufficiently frenzied, death ensued In the case of survivors, the symptoms were said to recur on the anniversary of the bite Particular descriptions of music were supposed to incite the patient to the excessive exertion necessary for his relief; hence the name 'Tarantella.'

"In the middle ages epidemics of 'tarantism' were of frequent occurrence and spread with alarming rapidity. They were seizures of an hysterical character, analogous to the ancient Bacchic dances, and quite unconnected with the venom of the spider from which they took their name. The condition of exaltation and frenzy was contagious, and would run through whole districts, with its subsequent relapse to a state of utter prostration and exhaustion. The evil reputation of the Tarantula appears to have exceedingly little basis in fact"

In California and the southwestern United States the term tarantula is applied to the very large spiders belonging to the family Aviculariidae also known as "bird spiders." Many of these spiders measure about five inches in spread of legs.

Eurypelma californica Ausserer is widely distributed in the southwestern United States. Baerg (loc. cit.) reports that "this tarantula has been credited with prodigious power in jumping (10 to 25 feet), and it is everywhere within its range or where its reputation has spread, feared greatly on account of its alleged poisonous nature.

"Many tests have been made with the poison of this tarantula On white rats and guinea pigs both the bite and injections have been employed. The injections were made by grinding up both poison glands in distilled water, and also in physiological salt solution On guinea pigs no serious effects have ever been observed. On white rat [illegible] four deaths have been observed. The bite and the [illegible] the bite of this tarantula is not fatal [illegible] definite symptoms. At first the rat runs about excitedly, [illegible] nd jerky manner. Then it becomes more quiet and appears to have considerable pain in the wounded leg. For much of the time the eyes are closed. In about four or five hours the rat shows evidence of recovery and in another hour it is normal

"On myself I tried the bite of this tarantula twice, and subsequently I have been bitten by accident. The relatively dull fangs produce a pain that may be

compared to that made by a pin prick. It lasts for only 15 to 30 minutes and is not accompanied by any inflammation or swelling."

Sericopelma communis Cambr is a large black species of tarantula common in the Panama Canal Zone, where it is generally feared. Baerg (loc cit.) allowed a spider of this species to bite him on the finger. He allowed only one fang to puncture the skin. The finger felt numb in a

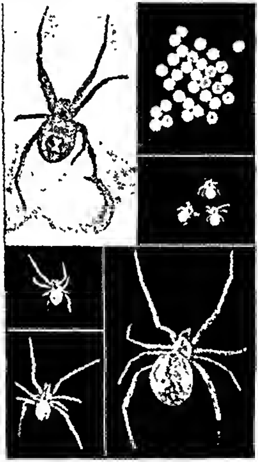

Fig 188—The black widow spider, *Latrodectus mactans* Mature female with egg sac, eggs; first instar spiders on right of egg sac, second and third instar spiders on left, fourth instar on right bottom

few minutes, and in 10 minutes the pain was quite severe. There followed considerable swelling of the finger, hand and wrist. After two hours Baerg put the hand in hot water for 30 minutes, when the pain and swelling subsided A lame feeling in the small and third fingers remained for several days Baerg concludes that although decidedly painful, the bite of this tarantula is probably not dangerous.

The Black Widow Spider[16]

Latrodectus mactans (Fabr.), now commonly known as the "black widow," was first described from America by Fabricius in 1775, under the name *Aranea mactans*. It belongs to the arachnid family Theridiidae. Like many other species the specific name of this spider has many synonyms, among them the following: *Lathrodectus malmignathus* var. *tropica* van Hasselt, *Latrodectus perfidus* Walck., *L. insularis* Dahl., *L. datatus* C. Koch, *L. apicalis* Butler. Many common names are also applied to this spider, among them in addition to "black widow" are "hourglass spider," "shoe-button spider," "Pokomoo," a name used by the California Indians who probably referred to this species as "a small black spider with a red spot under his belly," "cul rouge" (red rump) of Santo Domingo, "mico" of Bolivia, "lucacha" of Peru, "*Arana capulina*" of Mexico.

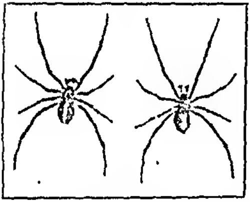

Fig. 189.—Male black widow spider, *Latrodectus mactans*. Dorsal view (left); ventral view (right)

The *adult female* is glossy black to sepia and densely clothed with short almost microscopic hairs which give it a naked appearance. An irregular white stripe, a remnant of nymphal pattern, is sometimes present on the dorsal anterior margin of the abdomen. The characteristic crimson hourglass marking on the underside of abdomen (Fig. 188), rarely altogether absent, varies among individuals from the distinct hourglass marking to a design comprising two or more distinct triangles or occasionally only an irregular longitudinal area. An occasional specimen has a crimson spot at the posterior end of abdomen on the dorsal side, just above the spinnerets. The abdomen is globose and often likened to a shoe button. The average width of the abdomen is 6 millimeters, or ¼ inch, and length over all (legs extended) about 40 millimeters, that is, about 1½ inches. The abdomens of the gravid females often measure 9 by 13 millimeters (⅜ by ½ inch).

The color pattern of the adult male (Fig. 189), while exhibiting considerable variation, approaches that of the immature female spider. Occasional mature males are almost black but retain some of the abdominal markings of the immature form. The terminal segment of each palpus appears like a large, black knob at the front of the head and contains the ejaculatory sexual apparatus, a portion of which resembles a coiled watch spring. The abdomen measures about 3 millimeters, or

⅛ inch, in diameter and the length over all is about 30 millimeters, that is, about 1⅛ inches.

Distribution and habitat.—This species, like most of the members of the genus, favors warmer climates, although it is abundant in many of our northern states. It has been reported in nearly every state of the United States as well as in Canada. The distribution of the black widow spider is reported as ranging from New Hampshire in North America to Tierra del Fuego in South America, including Mexico, Central America, and the West Indies, and it has been taken at an altitude of 8,000 feet in Colorado[17]

The increase in reported cases of poisonous spider bites has probably been the result of more accurate diagnosis as well as of the spider's gradual change of adaptation from its natural habitat to that of man's protective shelters

In its natural habitat the black widow spider is found with its web and egg sacs in protected darkened locations, such as vacated rodent burrows, under stones, logs, and long grass, in hollow stumps, and brush piles. It takes up its abode in man-made structures ranging particularly from the outdoor privy to such abodes as cellars, garages, hen houses, barns, pump houses, and the home The females and immature individuals are found most commonly in corners or in such locations as afford both protection and support for the web.

As a rule the females are not aggressive unless agitated or exceedingly hungry When guarding the egg sac the female, if disturbed, is particularly prone to bite.

The spider is present throughout the year but relatively more abundant in the late summer and early fall Many females have reached maturity by that time, while a few are carried over from the brood of the previous year. The mature males live but a few weeks. These observations coincide with the incidence of poisonous bites by months, i e., the majority of the spider-bite cases are recorded during July to October, inclusive

Once a web is established in a suitable location, the female spends the rest of her life feeding on the prey ensnared in this web and guarding such egg sacs as she may deposit

Feeding habits.—Whether the prey be a nocturnal moth, cricket, or domestic fly, the technique of capturing, killing, and finally sucking the fluids from the victim is very consistent The spider depends largely upon vibrations of the web as an indication of a trespasser, or prospective meal The coarse, permanent web is not particularly viscid in nature, but inadvertent insect visitors become temporarily entangled and in struggling to free themselves inform the owner of their presence The spider always approaches the victim backwards, extending a freshly

spun strand of viscid silk with either one or both hind legs, and attempts to tie down the thrashing appendages. If the captured prey appears particularly obstreperous, the spider ejects from the spinnerets large viscous droplets which dry quickly after the manner of rubber cement, and if the victim becomes entangled by these jets, escape is impossible. At about this point a lethal bite is usually administered. After being bitten the victim struggles violently, and in the course of a few minutes of progressively weaker tremors, dies. The body fluids are sucked from the trussed up victim at the leisure of the captor. After the meal is finished, all points of attachment between the remains of the prey and the web are cut loose, allowing it to drop from the web.

The diet of the black widow consists largely of insects of the locality, small spiders, and even centipedes and sow bugs. It is surprising to learn the number of insects that an individual spider consumes during its lifetime. Accurate records kept of the food of isolated specimens have totaled, in the life of an individual spider, as high as 250 houseflies, 33 vinegar flies (*Drosophila*), two crickets, and one small specimen of *Latrodectus mactans* (Fabr.). In considering the economic status of this spider its large diet of prevailing pests is a matter which should not be put aside lightly. It is interesting to note in connection with the diet that one individual (a male) was reared on a diet of its own species exclusively.

Mating habits.—After molting the last time the male leaves its web and seeks a mate. In this active, wandering state the male makes no attempt to capture prey but will occasionally suck up a small amount of water or liquid food if the opportunity is offered. If fortunate in finding a likely mate, the male vibrates his abdomen rapidly, causing the entire web to vibrate; the female may produce reciprocating movements. Cautiously the male approaches and strokes the female with his forelegs. It is a dangerous game the suitor plays, for if the female is not ready for his advances, death may result. On the other hand, if the female accepts his advances, the wooing begins. If agreeable, the female remains quiet and allows herself to be spun up in a delicate web. Once the web is successfully spun the male effects coitus by applying the spring-like apparatus of either palpus to the female genital opening. Occasionally this is repeated. After coitus the female easily frees herself and in many instances ensnares and feeds upon her mate. The infrequent observance and recognition of the male of *Latrodectus mactans* (Fabr.), together with the mariticidal habit of the female, has given rise to the name of [illegible] available, *often* [illegible] ural death. *In* the laboratory the males will readily mate a secon[illegible], [illegible]ut the *females* do not show such a tendency.

Comstock reports that in some male spiders the seminal fluid is transmitted from the sexual organs (in the abdomen), which lack any ejaculatory apparatus, to the palpi and is there stored for some time previous to mating. A delicate web appears to be spun upon which the fluid is emitted and then collected by the palpi. The process has been observed by us in *L mactans* (Fabr.).

Life history.—The life history of the black widow spider from egg to maturity requires about four months under laboratory conditions with ample food. The gravid female, when ready to deposit her eggs, forms a loosely woven cup of silk which hangs downward and while clinging inverted to its rim emits the eggs singly with rapid but regular upward flexures of the abdomen. The eggs, which appear to be forced into an expanding, gelatine-like film, gradually fill and adhere to the silken cup. The open end of the cup is then covered with loose strands of silk and the whole enclosed in a tough, water-tight covering of silk. The entire process consumes from one to three hours. Shortly after the egg sac is completed, the film surrounding the eggs seems to evaporate, and the eggs are free to roll about within their envelope. Egg-laying usually takes place during the night

In California these white or buff-colored egg sacs have been found suspended in webs out of doors from March to October, inclusive. Egg-laying takes place when the eggs are fully matured but may take place in the laboratory where food is plentiful throughout the year. The egg sacs (Fig. 188) measure from 12 to 15 millimeters (½ to ⅝ inch) in diameter, are usually oval in shape, and may contain from 25 to 917 (Lawson,[18] 1933) spherical eggs, each of which is about 1 millimeter (1/32 inch) in diameter. Females have been observed to spin from one to nine egg sacs a season. One spider under the writer's observation spun seven egg sacs; the eggs in the last one did not hatch. We have never observed egg deposition on the part of mature virgin females Fertile, mature females in isolation have produced egg sacs in the fall, and surviving the winter, have produced additional egg sacs the following spring, both groups of eggs being fertile.

The time between the deposition of successive groups of eggs varies from about one week to about four months. The incubation period depends on the temperature and at normal summer temperatures requires about 20 days in the interior of California, the observed extreme range being from 14 to 30 days. At a sustained temperature of 27° ± 1° C. the incubation period was about 30 days. The majority of the eggs usually hatch but not simultaneously. In the case of several egg sacs, each being formed by one female, the later lots appear to contain many sterile eggs.

The spiderlings after hatching spend some time—varying from four days in the summer to about one month in cooler weather—within the

egg sac before emerging from one or more small holes which they make in the tightly woven envelope. The first molt, previous to which the spider cannot feed, occurs from one to two weeks after hatching. Usually the entire first instar (and sometimes the second) is spent within the egg sac, and at emergence the molted skins are left behind together with the egg remnants. There is a tendency on the part of the spiderlings to cluster for a few days after emerging from the egg sac, and cannibalism rules during this time. The spinnerets appear to be capable of functioning at the time of emergence, but the extremely delicate web is capable of hold ing only the smallest of prey, such as gnats, mosquitoes, and other tiny spiders. The mother if confined with her young will not feed upon them even though extremely hungry.

Shortly after emerging and after a brief period of clustering, the nymphal spiders disperse by means of nearly invisible strands of silk. For several weeks they move about in the vicinity of their birthplace and suffer a high mortality from predaceous spiders, particularly and as already stated, from their own species. We have observed that when about one-third grown the female spiders establish themselves in some protected niche, construct small, loosely woven webs of their own, lacking in specific design, or, rarely, take possession of an abandoned funnel, sheet, or irregular web. Once settled they remain in the chosen lair, capturing progressively larger prey and extending the web as they approach maturity.

The number of molts that the black widow experiences varies, and the length of the intervening periods is even more inconstant, seemingly conditioned by the season and the amount of food assimilated. The average number of skins cast by the male is five. At optimum temperatures and with plenty of food this number is often reduced to three; under less favorable conditions, resulting in slower growth, a series of six skins may be shed. The sexes may be distinguished by the palpi, or feelers, which in the male are swollen or knob-like (Fig. 189), while the female possesses slender palpi. Subsequent to acquiring this secondary sexual character the male molts once (sometimes twice) before attaining maturity, at which time the web is abandoned, and his search for a mate begins.

The female takes longer to mature and has an average of seven molts, with a range from six to eight. When preparing to molt, nothing is eaten for several days. The old skin splits around the margin of the carapace, slips off the abdomen, and the spider then gradually pulls its legs free from its old sheaths, leaving the "ghost" of itself on or near the web The entire process requires about an hour. The newly molted spider is rather delicate and usually remains at rest for a day or so after molting Individuals occasionally die during the molting process.

paratively dark.

Second instar.—All eyes become darker and a black band extends down the

of the abdomen which remains whitish. On the underside of the abdomen the white area takes on a broad hourglass design outlined by a dark brown border

Third instar.—From this stage to maturity a wide variation in color pattern occurs Distinct lateral stripes begin to appear on the dorsum of the abdomen, in the region of the dots of the second instar. Intervening areas take on a pale greenish yellow cast, and the legs acquire four black bands, one at each end of the patella, one near the center of the tibia, and one at the junction of the tibia and the metatarsus The longitudinal white area on the underside of the abdomen becomes tinged with crimson.

Fourth instar.—Dark stripes or bands become distinct and faintly bordered with buff. The spinnerets take on a mottled appearance. Black bands at the leg joints become more distinct

Fifth instar—The central dorsal white stripe on the abdomen tends to be constricted at intervals and acquires a reddish tinge near the tip. All white

areas become more and more restricted Often a series of reddish spots are formed along the middorsal region of the abdomen.

Eighth instar—Only the females pass through this stage, which is often difficult to distinguish from the mature form. They are usually all black or sepia with the exception of the characteristic crimson markings and an occasional white band on the anterior margin of abdomen.

Longevity.—The length of life of individual spiders, as one might expect, varies with such factors as food supply, natural enemies, including man, etc. Under optimum conditions of food, temperature, humidity, etc , the complete life cycle from egg to maturity requires at least four months. Spiderlings emerging from eggs laid in July and hatched in August will, of course, pass the winter in an immature stage which thus materially extends the length of time required to complete the life history. Activity on the part of both the spiders and the insect prey is greatly reduced during the winter months and thus largely accounts for the retardation in development. When a brood emerges in late spring or early summer, the females generally reach maturity before cold weather sets in, but egg laying is held over until the following spring, and hence the life cycle is extended over a complete year. Mature males have not been found overwintering.

Under laboratory conditions a few females have lived through the second and third summers, giving a life span of nearly two years.

Spider bites.—While spiders in general have been considered poisonous, though largely erroneously so, for centuries, the group to which the black widow belongs in particular has been classed as poisonous for only about a century. Many of the early reports of spider bite traceable to the black widow came from the southern states and from 1889 to 1894 were frequently mentioned in Insect Life (Riley and Howard, 1889–1894). After the rapid increase in the population of California during the latter part of the nineteenth century, reports of poisonous spider bites began to be received from this state. In 1932 Bogen [19] listed a total of 380 cases from 18 states, of which 250 were from California. Numerous popular magazine and newspaper articles have appeared from time to time reporting local cases and warning the public of this arachnid.

Effect of bite on man.—The chain of symptoms resulting from the bite of the black widow spider is so striking that once recognized there is little danger of confusing it with that of other venomous forms or with an acute abdominal condition indicating surgical treatment. Cases of arachnidism, or spider-bite poisoning, have been incorrectly diagnosed by those unfamiliar with the symptoms as a ruptured gastric ulcer, acute appendicitis, renal colic, tabetic crises, tetanus, and food poisoning Abdominal incisions and post-mortems have revealed the intestine to be contracted nearly to the size of a lead pencil, resulting in a paralytic ileus.

The bite itself (similar to a pinprick) is not always felt and often there is but little evidence of a lesion. However, a slight local swelling and two tiny red spots may occur, and local redness is usually in evidence at the point of attack.

Pain, usually in the region of the bite, is felt almost immediately and increases in intensity, reaching its maximum in one to three hours and generally continuing for 12 to 48 hours, gradually subsiding. A rigidity and spasm of most of the larger muscle groups of the body (particularly those of the abdomen) are most notable. The abdominal muscles become "board-like," but local tenderness as in appendicitis is almost always absent. There is a slight rise in body temperature, increased blood pressure, a definite leucocytosis, and usually an increase in the pressure of the spinal fluid. A profuse perspiration is evident and often a tendency to nausea. The degree with which these symptoms are present varies in individual cases, and other symptoms such as chills, urinary retention, constipation, hyperactive reflexes, priapism, and a burning sensation of the skin are frequently reported.

Baerg,[20] who permitted himself to be bitten (basal joint of the third

finger of the left hand) by the black widow spider, when reporting on the effect of the bite, states:

"Referring briefly to some of the general effects of the case, I would say that the sharp pain in the finger, or rather in the left hand, was the most prominent feature. Very nearly as unpleasant was the aching pain which was most violent in the thick muscles of the lower part of the back, and present in almost all the muscles of the shoulders, chest, and legs. There was no marked tendency towards profuse perspiration I sweated heavily only when I first went to bed, and later after each one of the hot baths. I covered up well after these baths in order to bring about sweating, and I believe that it aided in recovery. There was no evidence of constipation. One dose of magnesium citrate brought fairly prompt results. On the day I left the hospital I took a second dose in order to facilitate recovery as much as possible."

Baerg's physician, Dr. E. F. Ellis, added the following note:

"The subjective symptoms in Mr. Baerg's case have been very graphically described by him. The objective symptoms would indicate, as observed by me, that there is a very marked phagocytosis locally around the area of the spider bite. The toxicity of the bite was such that the phagocytes very shortly offered no resistance to the systemic invasion of the poison. The poison in my opinion was partly transmitted through the blood stream and partly through the nerve trunk which in this case was the median nerve. Strange to say in this particular instance the patient had a marked vasomotor disturbance on the flexor side of the forearm, as was evidenced by a narrow strip something like an inch in width, extending up almost to the elbow in which there was very marked diaphoresis. This was present during the first 24 hours after the bite. The toxicity was also manifested by vasomotor changes in the lumbar muscles and muscles of the extremities, and in all the large joints of the body, as was shown by intermittent pains and symptoms similar to intermittent claudication There seems also to be a disposition, on his part, to unload very slowly, by elimination, the products of poison. More so than is the case with bites of any of the snakes including the rattler that I have observed"

Clinicol case records —The following case records from the Woodland (California) Clinic are typical of arachnidism:

CASE No. 1

Age: 41 Sex: Male Nationality: Dutch
Occupation: laborer. .Date admitted: 9-3-31. .Date dismissed: 9-8-31

9-3-31. About 8.30 P.M. on September 3 patient was taken with a sharp pain in the glans penis ... bout 15 to 20 minutes the p ... pain being steady, deep, an ... and rolled on the floor. His abdomen got hard with the onset of the pain. In about two hours pain had developed in the back. He was given two hypodermics (morphine) on entry which relieved him some but stated that he slept only one-half hour during night. Heat was applied to legs and back. Around 4 this

are not glandular in nature, hut function as absorptive organs which take up the poisonoua constituents from the body fluid of the spider. Sachs (1902) and Kobert in 1901 and 1906, according to Bogen, isolated from the spider body a specific poisonous principle named "arachnolysin" which they claim has a hemolytic effect on the blood of various animals (see also Hall and Vogelsang,[21] 1932). Our evidence relative to the venom of *Latrodectus mactans* (Fabr.) indicates that it acts primarily as a neurotoxin. Spider poison is not limited to the poison glands, but is also carried in the body fluids as pointed out by Sacha and by Kobert.

Blyth and Blyth [22] (1920) write:

"The Kara-Kurt of the Tartars, 'black wolf,' is *Latrodectus lugubris*, common in south Russia, and attaining a length of 2 cm. (3/4 inch). The Kara-Kurt poison is not only found in special glands, but is also diffused through the body. Kobert investigated this poison and stated that it is a generic type of the poison of spiders; the active principle is neither a glucoside, acid, nor an alkaloid. It does not dialyse, and drying destroys its activity; it has the characters of a toxalbumin, and has much similarity to the action of ricin and abrin. The Kara-Kurt poison dissolves the coloring matter of the red blood corpuscles even with a dilution of 1:127,000; it has a paralyzing effect on the heart, either due to action on the motor ganglia, or possibly a direct action on the muscle itself. The blood pressure sinks, the walls of the smallest arteries and capillaries become so changed as to allow the transudation of the blood and serum, producing punctiform hemorrhages and edema. This is best seen in the lungs. . . . The poison also has a paralyzing action on the central nervous system, hut it is not clear whether this action is primary, or whether it depends on the circulation troubles.

"The fatal dose of the poison, injected subcutaneously or intravenously, is extremely small. Cats are killed by quantities equal to 0 2 to 0 35 milligram per kilogram body weight. Repeated injections of nonfatal doses confer immunity."

Kellogg [23] (1915) states that high temperatures destroy the action of extracted black widow spider venom. It can withstand a temperature of 56° C. (132° F.) for 40 minutes, but is wholly destroyed if heated for 45 minutes at 70° C. (158° F.). The venom cannot be crystallized, since it is destroyed by desiccation. The best meana of preserving the extracted venom is in glycerin, where it can be kept for several months.

Treatment.—When bitten by the black widow spider, the patient should be treated with local antiseptics, such as tincture of iodine, at the point of injury to prevent secondary infection, kept as quiet as possible, and a physician summoned at once. Since, among other properties, the venom appears to be neurotoxic and its effect little short of instantaneous, first-aid measures are of little value.

Professional treatment for the bite of the black widow spider consists mainly in the use of opiatea, hydrotherapy, and similar measures to alleviate the acute pain. Medical records according to Bogen (1926, 1932)

list more than 75 different remedies and of all these, 3 seem to be outstanding as palliatives; namely, spinal puncture, intravenous injections of magnesium sulphate, and intramuscular administration of convalescent serum when given within 8 hours.

Gilbert and Stewart [24] point out that as "the toxin directly stimulates the myoneural junctions or that it acts on the nerve endings, to find a type of therapy which would have a direct depressant effect upon these structures would be ideal." Because calcium apparently depresses the neuromuscular junctions, Gilbert and Stewart selected calcium salts for the treatment of black widow spider bite. They report on this treatment as follows, "We found that intravenous injections of 10 per cent calcium chloride gave instantaneous and prolonged relief of the pain, and at the same time produced immediate relaxation of the muscle spasm so commonly seen in these patients. However, calcium chloride is not given thus without considerable danger. Its necrotic action on tissue outside a vein is only too well known. This danger is greatly magnified when its use is attempted in the treatment of children. Therefore, calcium gluconate (10 cc. of 10 per cent solution, intravenously), which does not have this objectionable feature, was used and found to produce equally as spectacular results as the calcium chloride. The intramuscular route, advisable for children, gave relief within a minute's time. Calcium lactate orally was ineffective as far as determined, probably because of its incomplete and slow absorption."

As Bogen (loc. cit., 1932) states, in part, ". . . despite its severe symptoms arachnidism is in the majority of cases a self-limited condition, and generally clears up spontaneously within a few days."

Control.—The black widow is frequently found in garages, basements, in living quarters, in old outbuildings, particularly privies, old barns, pump houses, stables, and woodpiles. Frequent disturbance of spider webs with a broom is suggested as well as crushing the spiders. Workers in dried fruit industries find numerous black widow spiders under the drying trays when turning the trays. The use of gloves is suggested in this instance. In the open the spiders inhabit vacant lots, open fields and hillsides, building their webs in crevices of rocks, between adjacent rocks, under logs, under projecting banks, in deserted squirrel or rabbit holes, under low wooden or concrete bridges, culverts, etc.

Since the egg sacs are conspicuous and are not carried about by the spider, they may be readily collected and destroyed. Great care should be exercised when collecting egg sacs because the female spider guards the sac closely and is particularly pugnacious at that time. The public should be encouraged to collect and burn or otherwise *destroy* the egg sacs of the black widow spider. Where accessible, the adult spider can be

brushed from its web with a broom or stick and stamped upon, or a suitable insect spray may be used to cause the spider to fall to the floor where it should then be crushed. The use of a blow torch when no hazard is involved is effective in the destruction of eggs and adult spiders as well. Because of the danger from spider bite when using privies in rural sections, it is suggested that the undersides of the seats and corners of the box be painted well with creosote or crude oil.

The adult female black widow spider is extremely difficult to kill with any contact spray. The common fly sprays act for the most part as moderate repellents, and at best only render the spider temporarily paralyzed. Of such chemicals tested, as carbon tetrachloride, carbon bisulfide, and a combination of ethylene dichloride and carbon tetrachloride, the first appears the most effective and paralyzes the spider almost immediately. However, in a few hours normal activity returns Kerosene applied as a spray will kill the spider in a few minutes; the increased fire hazard must be considered. A 1-per-cent solution of nicotine sulphate in water will usually kill the spider if thoroughly drenched with the spray, but this is not always possible because of the spider's habit of withdrawing into protected quarters when disturbed. Creosote, used as a spray, has proved to be the most effective material yet employed and, if the spider is contacted, death has resulted in every case observed. In addition to killing the spider the creosote acts as a repellent. Corners in garages, outbuildings, basements, etc., may be sprayed with good effect with a penetrating creosote. The immature spiders are much more readily killed than the adults and most of the above-mentioned chemicals are usually effective.

Natural enemies.—Under natural conditions the black widow spider is held at least moderately in check by its natural enemies. Among the various spider-hunting wasps and mud daubers there appear to be certain species which completely ignore this spider, as for example the yellow-marked mud dauber, *Sceliphron caementarius* Drury, while other species of mud daubers use the black widow spider to store their nests; thus Irving an [illegible] *Chalybion cyaneum* [illegible] black widow spiders had been stored in 15 nests, an [illegible] nest. The large San Diegan alligator lizard, *Gerrhonotus scincicauda webbii* (Baird), in southern California, has been suggested by Cowles[26] as probably an important factor in cutting down the incidence of this spide[illegible] er, tial. [illegible] ae and the chloropid fly, *Pseudogaurax signata* [illegible] Coq.), play an important rôle.

With protection afforded by man-made structures which exclude the natural enemies, the spider thrives and multiplies rapidly.

The chloropid fly, *Pseudogaurax signata* (Loew), can be reared successfully in captivity as proved by George Elwood Jenks, who has indicated his success to the author by correspondence and has beautifully illustrated the work of this interesting fly in the August, 1936, number of Popular Science Monthly. The larvae of this fly lie free in the egg sac and completely consume the eggs of the spider. The fly deposits its glistening white eggs on the outside of the spider's egg sac. The larvae hatch in five or six days and gain entrance into the sac by pushing their way through the fibres The length of the larval stage is eight to nine days, according to Kaston and Jenks,[27] and the pupal stage requires 11 to 12 days.

Other spiders.—Instead of being objects of admiration because of their beauty, many of the beautiful garden spiders or orb weavers are objects of fear These spiders are harmless and what is more, they are really beneficial because they feed on insects which may be harmful to the garden. The commonest of the garden spiders are *Miranda aurantia* (Lucas), the golden orb weaver, and *Argiope argentata* (Fabr.), the silvered orb weaver; both of these construct beautiful geometrical webs.[28] They belong to the family Argiopidae.

The remarkable trap-door spiders[29] represented by the California species, *Bothriocyrtum californicum* Cambridge, and the eastern trap-door spider, *Pachylomerus audouini* Lucas, belong to the family Aviculariidae already mentioned as including the tarantulas. The trap-door spiders are perfectly harmless.

The burrowing spider, *Brachythele longitarsus* Simon, commonly causes consternation in the home when winter rains and cold weather drive the spiders undercover. Like the trap-door spider, which it resembles, it is quite harmless.

Steatoda borealis (Hentz), belonging to the family Theridiidae, resembles the black widow spider rather closely but is slightly smaller, the color is sepia and it bears no red markings The egg sac is small and loosely woven. It is a harmless species

The banana spider, *Heteropoda venatoria* Koch, belongs to the family Heteropodidae and is frequently brought into northern fruit markets in bunches of bananas or other produce from the tropics. These rather large (spread of 3½ in), long-legged dark brown spiders are commonly mistaken for tarantulas. Their bite is painful but is not regarded as poisonous.

In the house as well as out of doors one commonly encounters the small jumping spiders, belonging to the family Attidae. Members of the

genus *Phidippus* may be seen stalking houseflies on the windows of the dining room or kitchen. These spiders have been known to bite, but so far as the author is aware, the effects were benign.

The "pruning spider," *Gliptocranium gasteroconthoides* Nicolet, is reported by Escomel [30] to be a particularly venomous species in Peru.

Venomous Ticks

Class Arachnida, Order Acarina

Ticks producing local or systemic disturbances by their bite alone are known in both families Ixodidae and Argasidae (see Chapter XXI), though more commonly in the latter.

Ordinarily little or no injury results from the mere bite of an ixodine tick—the writer has known of *Dermacentor occidentalis* Neumann and *Dermacentor variabilis* (Say) to remain attached to a person for days without causing great inconvenience and occasionally quite unobserved by the host. However, Nuttall (1911, loc. cit.) records a number of cases cited by other authors in which the bite of *Ixodes ricinus* (Linn.) has caused serious consequences, notably a case described by Johannessen of a "boy where the tick's body was removed but the capitulum remained embedded in the skin at the back of the head. Swelling followed at the point of injury, accompanied by headache, stiffening and cramps in the muscles of one side, partial loss of memory and polyuria; the pupils became dilated, etc. The boy made a slow recovery." The bite of *Ixodes ricinus* var. *californicus* Banks in California commonly results in more or less marked systemic disturbances.

Quite a number of species belonging to the family Argasidae are known to cause more or less serious consequences by their bites, notably *Ornithodoros moubata* (Murray), *O. coriaceus* Koch, *O. talaje* (G.-M.) and *O. turicata* (Dugès).

Ornithodoros moubata (Murray) has been reported repeatedly as causing marked disturbances by its bite. Wellman, as quoted by Nuttall (1908, loc. cit., p. 98), "states that the bite is very painful, the swelling and irritation (especially in Europeans) not subsiding for days. The wheals are hard, raised and swell most disagreeably if scratched, and this even a week after being bitten. The bite of young ticks (nymphae) is said by the natives to be more severe than that of the adults."

Ornithodoros coriaceus Koch.—This species (Fig. 191) occurs in the more mountainous coastal counties of California, having been first described from Mexico. The writer has collected it on Mount Hamilton where it flourishes in the deer beds among the low scrub oaks (*Quercus dumosa*). The following description of the species is a translation by Nuttall from the original:

"Shaped like the sole of a shoe, thick margined, roughly shagreened, yellowish-earthy color, spotted rusty-red, legs toothed dorsally. Length 9 3 mm. Body about twice as long as wide, width fairly uniform, indented on the sides,

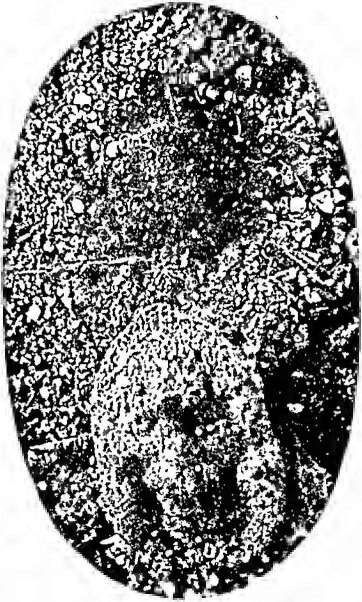

FIG 191—Showing *Ornithodoros coriaceus* just backing away from her eggs recently deposited in the sand. Note the protective coloration of the tick. × 5.

pointed above the mouth parts, rounded posteriorly, a thick turned-up border all around; the whole surface above and below thickly granulated like fish skin (shagreen), the granules flat above, consequently, the whole leathery, on the back unequal folds and grooves. Beneath in the front of the body a deep groove

running to the stigmata and on the inner protrusion the rather large round quite clearly marked eyes. The coxae gradually thicken toward the distal extremity and are somewhat bent; the other articles somewhat compressed and clearly notched or round toothed. The whole surface, above and below, dirty yellowish-earthy color, rusty-red spots irregularly distributed throughout. Capitulum and palps light yellow. Legs gray-brown. Female. Habitat: Mexico."

The pajaroello is more feared than the rattlesnake by the natives, and many harrowing tales are told regarding the loss of an arm or leg, or even death resulting from the bite of it. Much of this is gross exaggeration. Dr. W. L. Chandler, formerly a graduate student in the University of California, has given the writer an accurate account of two bites which he suffered while stationed in the San Antone Valley (California). The first bite was received July 2, 1912. He experienced a sharp pain on the left arm and upon rolling up his sleeve discovered a large tick, partly engorged, attached to the upper arm in front. He dislodged the tick and sucked the lesion. The lesion when first discovered showed a small dark purple ring surrounding a bright red spot, the point of attachment. The discoloration disappeared in a short time, but the arm was "highly irritable for two or three days and at the point of attachment a minute clear scab formed." The tick proved to be a "pajaroello."

The second bite took place July 16 while he was seated in a thicket of willows (the first bite had occurred while he was riding over a brush-grown hill), and in this case the sharp pain involved the left leg. An almost fully engorged tick (again a pajaroello) measuring about three-quarters of an inch in length and about one-half inch in width was removed from just above the shin. Once more a bright red spot was visible at the point of attachment, surrounded by an irregular purple ring about three-quarters of an inch in diameter. In about an hour the leg began to swell in the vicinity of the lesion, and in about three hours the entire lower leg was tremendously swollen. The coloration about the point of attachment had widened considerably, was puffy and a clear lymph exuded freely from the lesion. The young man lanced the wound, causing the blood to flow freely, and treated it with crystals of potassium permanganate, binding the leg with cotton and gauze. During the following night he reports experiencing a generally disagreeable feeling, the entire lower leg "irritable and numb." On the following day the bite on the arm became irritable again and was treated as had been the leg, as he feared bad results. For several weeks both lesions exuded a clear lymph from beneath an "oily-looking, transparent, red mottled scab" which remained in evidence for two or three months.

Life history of Ornithodoros coriaceus Koch.—The pajaroello deposits large plum-colored spherical eggs (Fig. 191). In the laboratory

these are deposited on the sand in slight depressions. There are commonly four to seven layings at intervals of from several days to several weeks during the months of May to July, inclusive (as early as February under laboratory conditions), and the female is known to deposit eggs for at least two successive seasons. The greatest number of eggs observed at one laying was 802, with a total of 1,158 for one season. The incubation period at a maintained temperature of from 24° to 26° C. is from 19 to 29 days, with an average of about 22 days

The larvae (Fig. 192) are very active, scattering quickly and attaching readily to a host, particularly rabbits in the laboratory. Experimentally the human may also serve as a larval host. The ear of a rabbit apparently affords a most satisfactory point for attachment. The larva

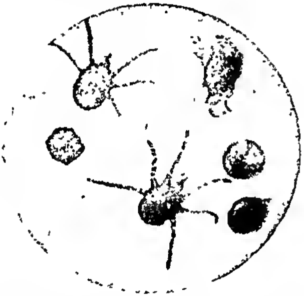

Fig 192.—Showing egg of *Ornithodoros coriaceus* and larvae of the same in the act of emerging; also two fully emerged individuals × 14.

remains attached to the host for a period of about seven days, becoming quite globular and much enlarged.

Under favorable conditions the tick becomes sexually differentiated after the fourth molt, requiring about four months to reach this stage. Others have not become sexually differentiated with five molts. Ordinarily the tick molts once for each engorgement, but there may be two molts between feedings.

Remedies for tick bites.—For the bite of *Ornithodoros moubata* (Murray) Nuttall "recommends prolonged bathing in very hot water, followed by the application of a strong solution of bicarbonate of soda, which is allowed to dry upon the skin. For severe itching he

advises smearing the bites with vaseline which is slightly impregnated with camphor or menthol." Medical aid should be sought when complications arise.

Scorpions

Class Arachnida, Order Scorpionida

General characteristics.—Scorpions are easily recognized by their more or less crab-like appearance, but particularly by the presence of the long fleshy five-segmented tail-like postabdomen terminating in a bulbous sac and prominent sting. (Fig. 193.) The pedipalps are greatly enlarged and the last two segments form strong lobster-like chelae or pincers. The *true jaws, chelicerae*, are small and partly concealed from above by the front edge of the carapace. There are four pairs of terminally clawed legs throughout life.

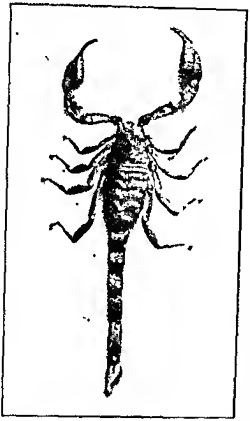

FIG 193.—A scorpion, *Hadrurus hirsutus* × .6

The cephalothorax bears a pair of conspicuous eyes near the mid-dorsal line (median eyes), and several smaller ocelli in groups of from two to five, on the lateral margins (lateral eyes). Some species are blind. Scorpions breathe by means of lung books. They are ovoviviparous, and when the young are born they are carried attached by their pincers to the body of the mother. Although the sexes are very similar in appearance, the males have a longer cauda and the chelae are broader.

Scorpions are found most commonly in tropical and subtropical countries. They are nocturnal, remaining hidden during the day beneath loose stones, loose bark of fallen trees, boards, piles of lumber, under floors of outbuildings, and under debris. They feed upon larger insects and spiders, which they seize with their chelae and sting with their powerful sting, which is thrust forward over the scorpion's back.

Scorpion sting.—The "aculeus" or sting of the scorpion is situated terminally on the final bulbous segment. The bulbous segment contains

a pair of venom glands which are separated by a muscular septum. From the glands are given off fine efferent ducts opening at the apex of the sting (Pavlovsky [31]). The sting curves downward when the "tail" is extended, but upward and forward when the scorpion poises for attack or defense, the entire tail-like postabdomen (tail) being curved dorsally and forward. The victim is struck quickly and repeatedly, the thrust being made quite close to the front of the carapace.

The *venom* is a transparent liquid, acid in reaction. The toxic principle is said to be a neurotoxin. "It also has a lecithide which haemolyzes nucleated as well as nonnucleated blood corpuscles. . . . Although the sting of a scorpion is very painful, the poison as a rule does not produce general symptoms in adults, but in children under five years of age the sting frequently causes death," according to Waterman,[32] whose notes on the subject of scorpion poisoning should be consulted by physicians concerned with this matter. Waterman states that the "diagnosis is generally easy if a history of the sting is obtained, a slow full pulse easily compressible, with rapid respirations, a pulse respiration ratio of 3:1, 2:1, or 1:1; salivation, vomiting, glycosuria and epigastric pain and tenderness—a characteristic picture of scorpion sting." The puncture made by the aculeus may be visible.

The symptoms caused by the sting of the Durango scorpion, *Centruroides suffusus* Pocock [*Centrurus gracilis* (Latreille)?], are described by Baerg [33] as follows:

"Immediately following the sharp pain produced by the sting is a feeling of numbness or drowsiness, then there is an itching sensation in the nose, mouth and throat that makes the victim distort the face, rub nose and mouth, and sneeze. There is at first an excessive production of saliva; this and a curious feeling that is described as the sensation of a ball of hair in the throat, induce the victim to swallow as rapidly as possible. The tongue is sluggish, so that communication is often by signs The muscles of the lower jaw are contracted so that it is difficult, or impossible, to give medicine through the mouth. There is a disorder of movements in arms and legs The temperature rises rapidly to 104° or 104.8° F., the salivary secretion now diminishes and there is a scarcity of urine. The senses of touch and sight are affected, objects appear large on touching them, hair feels rigid, face feels bulky, a veil seems to be interposed between the eyes and various objects, strong light is unpleasant to patients Luminous objects, such as a candle, are surrounded by a red circle Frequently there is a pronounced strabismus. There may be a hemorrhage of the stomach, intestine and lungs. The convulsions come in waves and increase in severity

danger; yet death may occur six to eight hours after the patient was stung It is then probably due to nervous exhaustion following the long periods of convulsions."

The African scorpion, *Buthus quinquestriatus* Hemprich and Ehrenberg, of Egypt and northern Africa is said to produce similar symptoms. The mortality due to the sting of this scorpion is said to reach 60 per cent in children under five, but diminishes with age.

The order Scorpionida is divided into six or seven families, depending upon the author. These are Scorpionidae, Buthidae, Vaejovidae, Chactidae, Ischnuridae, Bothriuridae, and Chaerilidae. According to Ewing[34] four of these families occur in the United States and northern Mexico, and are separated as follows:

A.[1] Sternum subpentagonal, with sides almost parallel.
- B.[1] Membrane at base of last tarsal segment of most of the legs with a single spur; postabdomen frequently reduced......Scorpionidae
- B.[2] Membrane at base of last tarsal segment of most of the legs with two spurs.
  - C.[1] Only two ocelli on each lateral margin of carapace......Chactidae
  - C.[2] With three to five ocelli on each lateral margin of carapace Vaejovidae

A.[2] Sternum triangular, the sides [illegible] mem-brane at the base of last [illegible] unbranched spurs; fixed a[illegible] Buthidae

Over 300 species of scorpions are known.

Family Buthidae.—This is the most widely distributed of the families of scorpions and is distinguished from the other American families by the shape of the sternum which is triangular, the sides being strongly convergent anteriorly (Ewing). To this family belongs *Centruroides suffusus* Pocock, the so-called Durango scorpion, the common scorpion of the State of Durango, as well as other neighboring states in Mexico and portions of Arizona. During the period from 1890 to 1926, according to Baerg (1929, loc. cit.), "a period of 36 years, there have been 1,608 deaths" from scorpion stings in Durango. The majority of victims are children from one to seven years. The symptoms caused by the sting of this scorpion are described above.

Centruroides vittatus (Say) [*C. carolinianus* (Wood)] is the common striped scorpion of the United States. It is widely distributed, having been reported from Georgia, Florida, Kansas, Texas, Arkansas, Louisiana, New Mexico and South Carolina. Concerning the sting of this species, Ewing (1928, loc. cit.) writes, "The writer has induced this species to sting him and has observed the effects of its sting on others. At the time of the stinging there is a sharp pain, but this soon subsides. A small swollen area, or wheal, usually develops about the puncture point. This soon disappears. There are no permanent effects of the sting reported for the species as far as known to the writer."

Centruroides nigrescens (Pocock) is known as the black scorpion. It is reported from Texas and Mexico. It measures 10 cm. in length, and is dark chestnut-brown to jet-black.

Centruroides californicus (Girard) is the striped scorpion of California. It resembles *C. vittatus* (Say) very closely.

Buthus quinquestriatus Hemprich and Ehrenberg is a common Egyptian and North African species, more especially in upper Egypt, according to Wilson,[35] who states that it is of a sandy yellow color tending to brown, and measures about 10 cm. in length. That author also states that it is undoubtedly the commonest species in that region and is generally thought to be the most dangerous; it is frequently found in houses and is the species in all probability giving rise to the numerous cases of scorpion sting said to be not uncommonly fatal in upper Egypt.

Family Scorpionidae.—According to Ewing this family is well represented in Central America and the tropical regions of the Old World, but is poorly represented in the United States.

Diplocentrus whitei (Gerv) is a very dark reddish brown scorpion from 5 to 7 cm. in length. This species has been taken on the Mojave Desert, California. Ewing writes that he has been inclined to associate serious scorpion stings with this species, because of the descriptions given by persons living near the Mexican boundary who have had experience with cases of severe scorpion sting On the other hand, Baerg (loc. cit.) states that several punctures from two scorpions failed to produce any appreciable effect on him except the slight pain of the puncture.

Family Chactidae.—This family differs from all other North American scorpion families in having only two ocelli on each side of the carapace.

Broteas alleni (Wood) is a small dark brown species measuring about 3 cm. in length. It has been taken in lower California and at Fort Tejon, California.

Family Vaejovidae.—This is the best represented family in North and Central America. It contains a number of very large species.

Hadrurus hirsutus (Wood) (Fig 193) is the giant hairy scorpion, our largest species, measuring 11 to 12 cm. in length. The body is dark yellowish and hairy. It is found in southwestern United States and northern Mexico. The writer has taken this species in the Imperial Valley, California.

Hadrurus aztecus Pocock is the Mexican hairy scorpion and closely resembles *H. hirsutus* (Wood).

Vaejovis spinigerus Wood is the stripe-tailed scorpion. It has four longitudinal dark stripes on the underside of the "tail." It measures from 5 to 8 cm. in length. It is a typical desert species, occurring in rocky

waste places of Texas, New Mexico, and California, where it is common. Baerg (loc. cit.) reports that its sting caused only a slight pain which disappeared in less than half an hour; its poison had no appreciable effect on white rats.

Vaejovis boreus (Girard) is the northern scorpion occurring in North and South Dakota, Idaho, Wyoming, Nebraska, and Montana. It is a dark, yellowish brown, unmarked species measuring from 3.5 to 5 cm in length. Its sting, though painful, is benign in effect.

Uroctonus mordax Thorell is the mordant scorpion, a dark brown medium-sized Pacific coast species. It is the commonest species in the San Francisco Bay region. Its sting is about as painful as that of a yellow jacket, but causes as a rule less swelling and the effects soon disappear. It occurs under loose rocks, beneath bark of fallen trees, under rubbish, tent floors, and the like.

Scorpion control.—The scorpion hazard on premises may be largely reduced by the elimination of favorable hiding places, such as boards, loose rocks, rubbish, platforms, and the like. Creosote sprays have a substantial repellent effect, but unless a clear solution can be obtained, may not be desirable about the yard. In some localities where scorpions are abundant and dangerous a bounty has been paid. Thus Baerg (loc. cit.) reports that in 1928, May 1 to July 31, 12,911 scorpions were collected in and near the city of Durango by scorpion collectors (alacraneros), and a bounty of two and one-half cents for the females and two cents for the males was paid. Baerg also states that Dr. Brachetti advises that the "powder of chrysanthemum will drive scorpions away, or even kill them, and so does creoline—a dilute solution of creoline to be sprinkled on the floors and on the flower beds about the house."

Whip Scorpions

Class Arachnida, Order Pedipalpida

Characteristics of Pedipalpida.—The Pedipalpida are tropical and subtropical arachnids although very unevenly distributed. They are said to be absent from Europe and North Africa (Savory). The term "whip scorpion" is applied to the Family Thelyphonidae because the terminal end of the abdomen is provided with a long, slender, many-segmented appendage (Fig. 194). Vinegarroon is a common name.

The giant whip scorpion, *Mastigoproctus giganteus* (Lucas), occurs in Florida where, according to Ewing,[36] it is found on the ground under various litter and under logs, under boards and lumber lying on moist ground. It feeds on almost all kinds of larger insects and other arthropods if not too hard or too active. A closely related species, *if not iden-*

tical, occurs in southern California, mainly in sandy desert places where it burrows in sand under debris. They are commonly regarded as poisonous, although they cannot sting but may bite. The writer has found that many persons living in the arid parts of California fear this creature very much, but knows of no evidence to justify this fear. Ewing states that on no occasion was there more than a trivial mechanical effect from the bite, similar to that of a slight pinprick. He states that when handled it gives off a repellent fluid which has the odor of vinegar. This fluid may possibly produce some irritation to persons with a tender skin

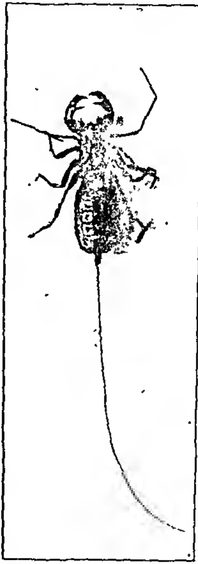

Fig 194.—Whip scorpion (Pedipalpida) *Mastigoproctus giganteus* × 3

Solpugids

Class Arachnida, Order Solpugida

Characteristics of the Solpugida.—The solpugids (Fig. 195), commonly known as "sun spiders" and "wind scorpions," are in general appearance spider-like, although there is no pedicle; they are very hairy, largely nocturnal, occurring mainly in desert, tropical and subtropical regions. They are common in many parts of California and have been reported as far north as Nebraska. The chelicerae are large and powerful and are two-segmented. The second segment is movable and articulates in such fashion as to work in a more or less vertical plane. Food is crushed to a pulp, the fluid is swallowed, and the hard parts are ejected. The first pair of legs are used as tactile organs. Respiration is tracheate. They are commonly but erroneously regarded as exceedingly venomous. The writer has been told that the presence of one of these animals in a watering trough would result in the death of any animal drinking from the same. There is evidently not the slightest foundation for this belief. Although these animals are able to

inflict a painful bite by means of their powerful jaws, the effect is fleeting. Poison glands are absent.

There are said to be only twelve species in the United States, all but one belonging to the two genera, *Eremobates*, e.g., *Eremobates formicarius* (Koch) and *E. formidabilis* (Simon); and *Ammotrecha*, e g, *Ammotrecha limbata* (Lucas).

Centipedes

Class Myriapoda, Order Chilopoda

Characteristics of Myriapoda.—The Myriapoda are worm-like animals with separate head, possessing antennae, and many fairly

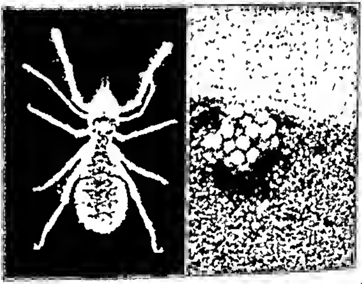

Fig. 195.—A solpugid, commonly called sun spider. Eggs on right.

similar segments, each possessing one or two pairs of segmented appendages. Like the insects they are tracheated and for the most part terrestrial.

The class Myriapoda is divided into four or five orders among which are Chilopoda, the centipedes, with only one pair of appendages to each ... pairs of appendages ... incipally ... Koch, a so-called "thousand-legged worm."

Characteristics of centipedes.—The Chilopoda have only one pair of appendages to each segment which are widely separated at the bases, the antennae are many-jointed, the genital pore is located on the terminal body segment. The larger species, at least, are predaceous, feeding

mainly on insects. Notwithstanding the confusing abundance of walking appendages, the centipedes crawl very rapidly.

Unlike the millipedes, which possess no organs of defense except glands which secrete an offensive odor, the centipedes are provided with powerful poison claws located immediately ventral to the mouth and connected by means of a hollow tube with large poison glands. The first pair of legs which terminate in these claws are bent in position to form maxillipeds.

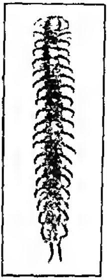

FIG 196.—A venomous centipede, *Scolopendra heros* × 66.

The larger centipedes (Fig. 196) are commonly regarded as venomous and are generally much feared. Large insects are quickly killed when the poison claws close upon them. It is true that the larger species belonging to the genus *Scolopendra* and even the smaller house centipede, *Cermatia* (=*Scutigera*) *forceps* (Raf.), are able to pierce the skin with their poison claws and cause severe pain with some swelling at the site of the bite. Cases are reported showing a double reddish streak on the skin where the centipede had crawled. This condition may be caused by the dragging sharp tips of the terminal pair of legs. Among the several formidable-appearing species of the genus *Scolopendra* are *S. heros* Gir of southern United States, *S. polymorpha* Wood of the southwestern states and Mexico, *S. viridis* Say, a Mexican species, and *S. sumichrasti* Sauss. from the Canal Zone. All of these species may reach a length of from five to six inches. Many of the centipedes are markedly phosphorescent, notably *Geophilus electricus* (Linn.) and *G. phosphoreus* Gervais.

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CHAPTER XXIV

UTILIZATION OF ARTHROPODS IN MEDICAL PRACTICE

Introduction.—Certain insects and other arthropods have been used in the practice of medicine for centuries, mostly in the form of infusions, though often employed in weird and revolting practices. There are many uses to which arthropods and their products are put in modern practice; some of these will be enumerated in this chapter.

Early uses.—Beetles have contributed a notable list of remedies, as the following extracts from Kunzé's Entomological Materia Medica[1] (1893) indicate. *Coccinella* (i.e., ladybird beetles) have been recommended for toothache if one or two beetles are mashed and put in the cavity of the tooth; this was also considered a very efficacious remedy for colic and measles.

The mandibles of *Lucanus cervus* Linn., the stag beetle, were employed under the name of "horns of scarabaei" as an absorbent in cases of pains or convulsions. Presumably the same beetle has been recommended to be worn as an amulet for "an ague or pains, and contraction of the tendons if applied to the affected parts, and if tied to the necks of children it enables them to retain their urine." The oil prepared from this beetle by infusion was dropped into the ears for earache.

Mouffet, in his *Theatrum Insectorum* (1634), states, according to Kunzé, that "the beetle engraven on a emerald yields a present remedy against all witchcraft, and is no less effectual than that ruby which Hermes once gave Ulysses. . . . It keeps away likewise the headache, which truly is no small mischief, especially to great drinkers."

Cockroaches, crickets, grasshoppers and other Orthoptera were also commonly used. *Pulvis tarakanae* is a medicine made of *Blatta orientalis* Linn. or *Blatta laponica* Linn. and was recommended for pleuritic effusion and pericarditis. The "ashes of *Gryllus domesticus* Linn. are said to be diuretic; the expressed juice dropped into the eyes is a remedy for weakness of the sight and alleviates disorder of the tonsils, if rubbed on them. . . . The *Locusta africanus* (a grasshopper) is a very good antidote against the poison of the scorpion."

Spiritus formicarum was made by macerating two parts of the bruised ant, *Formica rufa* Linn., in three parts of alcohol and then filtering before use; it was long known as a rubefacient. The oil of *Formica major*

Linn. obtained by infusion was said to be good for the gout and palsy. *Oleum formicarum* is asserted to be more powerful than the spirits for gout and rheumatism.

Bees, medicinally known as *Apis*, have long been looked upon with favor in medical practice. Early writers, according to Kunzé, state that when dried, powdered and taken internally they are diuretic and diaphoretic.

Roasted *Cicada* has been recommended to be eaten for pains of the bladder. *Coccus cacti* Linn. or cochineal is suggested for whooping cough and neuralgic affections and a tincture *Cimeceum* made of bedbugs, *Cimex lectularius* Linn., has been highly recommended for tertian agues and helminthic infestations.

Spiders and their webs have been used in the treatment of disease and injuries for centuries and some of these practices still persist. The author has seen untreated cobwebs used to stop the flow of blood from severe cuts. Pills of cobwebs are used, it is said, for headache, insomnia and numerous other ailments. *Tela araneae*, tincture of spiders, is still included among unofficial drugs which may be purchased if desired. The tincture is said to be a remedy for toxaemia, malignant ulcers, hysteria, etc. There is reported to be an important difference between the tincture of the Cuban tarantula and that of the Spanish tarantula.

Waterman (1938, loc. cit, p. 541), states that the natives of Trinidad have great faith in their methods of producing immunity to scorpion poisoning; namely (1) fry a few scorpions and eat them; (2) smoke the scorpion in a pipe; (3) place some scorpions in rum for a week or two and then drink the contents.

Spanish fly.—*Lytta vesicatoria* (Linn.) is a species of beetle belonging to the family Meloidae which occurs in southern Europe, particularly southern France and Spain. It is a golden-green to bluish species ranging from one-half to three-fourths of an inch in length. It is collected principally from such vegetation as ash, privet and lilac. The larvae are subterranean and predaceous in habit.

The term *cantharis* was early employed to designate this group of beetles. Indeed, the term "*canthariasis*" is still used to designate an intestinal or gastric infestation of coleopterous insects. The term *cantharis* is also applied to a genus of "leather-winged" beetles, closely related to the true blister beetles of the family Meloidae from whose bodies pharmaceutical cantharidin is derived.

Cantharidin is a crystalline principle, the anhydrid of cantharidic acid, isolated by Robiquet in 1812 from the Spanish fly, *Lytta vesicatoria* (Linn.). Cantharidin penetrates the epidermis quite readily and produces even in very small quantity (1/10 mg.) violent but superficial irritation resulting in vesication in a few hours. Even when applied to the

skin cantharidin irritates the kidneys so that "fly blisters" are contraindicated in nephritis. It was formerly used as an aphrodisiac, but its effects may be dangerous to life, hence its use for this purpose has been largely discontinued.

Malaria therapy of paresis.—The treatment of general paresis of syphilitic origin by means of artificially induced malaria is now a well-recognized practice, having been first used in 1917 by Wagner-Jauregg in Vienna.

Boyd [2] points out that the principal requisite for the prosecution of naturally induced malaria therapy throughout the year is a sufficient supply of anopheline mosquitoes, preferably secured by rearing. Also a further requisite is a continuous supply of patients for whom malaria therapy is indicated, in whom the strains of malaria parasites may be successively propagated. Boyd used routinely *Anopheles quadrimaculatus* Say reared in an insectary and a strain of *Plasmodium vivax*, known as the Boyd strain. He states that negroes show a high degree of tolerance, and in none was the attack of malaria of sufficient duration to be of any therapeutic benefit. For negroes, Boyd, Stratman-Thomas, and Kitchen [3] employ *Plasmodium falciparum* routinely, applying six or eight infected mosquitoes. In the case of *P. vivax* inoculations for white patients not less than four infected mosquitoes are applied.

Mosquitoes incubating the parasites are kept at a temperature of 20° C. with a relative humidity of approximately 85 per cent. On about the third day after emergence the mosquitoes are fed on an infected patient in whose blood there are both male and female gametocytes. Exflagellation should be observed in order to insure a good supply of infected mosquitoes. "The salivary glands of the mosquitoes were not usually found positive for sporozoites before the sixteenth day after the infecting meal." In the interval between feedings on patients the mosquitoes are kept at a constant temperature of 23° C. Infected mosquitoes may be used repeatedly. A single infectious mosquito has been successful in infecting as many as 11 individuals. If kept at a low temperature, infected mosquitoes may live for many days; at least 125 days have been reported, during which the insects may be shipped long distances.

Reporting on mosquito-induced malaria by the Boyd strain of *P. vivax* in the treatment of general paresis at the Manhattan State Hospital, Kusch, Milam and Stratman-Thomas [4] state that "after the incubation period of 8 to 18 days (usually on the eleventh to the fourteenth) there was an acute rise in temperature to about 40° C. followed by daily paroxysms and remissions. Chills most frequently started one day to four days after onset of the high temperature." These investigators state that when possible all patients were allowed to proceed to a spontaneous termination of the malaria. In comparing the results of blood-

inoculated malarial and mosquito-inoculated malarial patients, they found that there were approximately twice as many paroxysms per patient in the latter as in the former, i e., 8 to 12 in blood-inoculoted and 24 in mosquito-inoculated; also they believe this factor of duration of the malaria course to be the significant one in the results obtoined. "Malaria induced by mosquito bite for treatment of general paresis apparently gives better results than thot produced by direct blood inoculation, and is the method of choice for the treatment where facilities for its use are available."

Malaria therapy in arthritis.—In view of the fovorable results often obtained in rheumatoid orthritis by intravenous injection of typhoid vaccine, a test was made by Cecil, Friess, Nicholls ond Stratman-Thomas [5] of malarial therapy in the treatment of this disease. Specimens of *Anopheles quadrimaculatus* Say infected with *Plasmodium vivax* were used on twelve patients; the thirteenth received a quartan infection The number of paroxysms allowed to each patient voried from 3 to 15, the average being 10. The investigators report that

"all thirteen of the patients received immediate benefit from the treatment. In a majority of cases the improvement was striking, practically all pain and swelling disappeared from the affected joints after three or four malarial paroxysms In the course of from four to six weeks after termination of malaria all but two of the patients had more or less recrudescence of joint symptoms, and one of these two suffered a complete relapse later on. The one exceptional patient who did not relapse had had arthritis for only four months at the time malarial therapy was administered"

Surgical maggots.—Although now largely discontinued in favor of other treatments, the use of sterile maggots, maggot therapy, in the disinfection of osteomyelitis and other infected wounds was introduced into professional medical practice by Baer shortly after the end of the World Wor (Baer, 1931)[6]. Baer had noticed that when men wounded in battle had been lying out on the ground for some time before being carried into dressing stations, their wounds were infested with maggots. He noticed particularly that these men whose wounds were crawling with maggots did not develop infections, os did the men whose wounds had received early treatment. It wos discovered thot the maggots were eating the dead tissue in which the bacterial infection throve; the maggots octually served as o "vioble antiseptic." Baer's work attracted a great deal of ottention and much experimentation followed, resulting in numerous publications by many investigators.

In 1932 Livingston and Prince [7] reported that filtered, uncontaminated products derived from the bodies of larvae in culture, when brought into contact with pyogenic organisms in petri dishes, destroyed the cultures.

The fly larvae used in earlier osteomyelitis treatment apparently belonged indiscriminately to the following species, namely, *Lucilia sericata* (Meig.), *L. caesar* (Linn.) and *Phormia regina* (Meigen). It was assumed that all these species fed only on dead tissues. Stewart[8] has shown that even *Lucilia sericata* (Meig.) larvae which have been most commonly used in practice will establish themselves in and feed upon normal healthy tissue, although they prefer necrotic tissue. He warns that they, and probably the larvae of *Phormia regina* (Meigen), *Lucilia caesar* (Linn.) and *Wohlfahrtia nuba* (Wiedemann), are potentially dangerous to normal tissue and must be utilized with care by an experienced person.

Stewart[9] also came to the conclusion that not only the scavenging activities of the maggots play an important rôle in the successful results obtained, but that the calcium carbonate, which was found to be constantly exuded by the larvae, is also of importance because of its property of alkalinizing the wound and of markedly increasing phagocytosis. Robinson in his later investigations discovered that allantoin and urea are present in maggot excretions, and that both have good effect in the treatment of osteomyelitis; however, because of its low cost and high solubility the urea is now generally used, thus largely disposing of the use of maggots.

The production of sterile maggots if these are desired begins with the sterilization of eggs, which must be completely separated so that the individual eggs may be wet with the disinfecting fluid. The following procedure is outlined by Robinson:[10]

"As a practical egg disinfectant formalin compares very favorably with the numerous other solutions tested, and in some respects it is the most satisfactory one tried. Immersion of the eggs in a 5 per cent solution of formalin plus 1 per cent sodium hydroxide for five minutes has been found sufficient to produce steril[illegible]

"[illegible] (1[illegible] mg. in weight) are placed in a test tube of the [illegible]y. After 5 minutes most of the solution is decanted a[illegible] then washed. A widely used method of washing devised by [illegible] Gooch crucible sup[illegible] [illegible]ghly with water.

[illegible] best in small lots. The principal [illegible] loss in discarding the lot [illegible] to 1,000 maggots seem preferable. For lots of that size shell vials about [illegible] high and 35 mm. wide, or wide-mouthed specimen bottles, make satisfactory food containers. The containers are plugged with gauze-covered cotton and are sterilized in a hot-air oven at 150° to 160° for one hour. The food is introduced next.

"Two types of sterile food are available. One type permits rapid growth of the maggots, but necessitates the retardation of their growth in cold storage during the sterility tests which are described later. The objection to cold storage

is that it causes a high mortality of the maggots. However, if this food is used,

"The other type of food permits only a slow rate of growth of the maggots up to the time of implantation but does not interfere with their feeding and rapid growth in the wound. This food, devised by S. W. Simmons, consists of equal parts of whole sweet milk and water to which is added 1.5 per cent plain agar. The mixture is boiled for three to four minutes and about 10 cc. is poured into each container. Advantages of this retarding food are that it eliminates the cold storage of maggots during the sterility tests, and it permits the technician to hold surplus maggots in reserve for a few days without chilling and consequent mortality. The food is cheap and very easy to prepare. It also makes possible the shipment of sterile maggots long distances without ice packing.

"After the food is added, the containers are replugged and autoclaved for 30 minutes at 15 pounds' pressure and stored in the refrigerator until used. The eggs are introduced into the food bottle by transferring them upon the bandage gauze directly from the Gooch crucible to the bottle. The bottles are then placed in either the fly or the larva cabinet for hatching. The cloth may be removed from the bottle after the eggs have hatched."

Tests for sterility of maggots.—Robinson states that in

"about 48 hours after hatching, each lot of maggots is tested for sterility. A reliable and simple procedure is to test some of the partly liquefied food upon which the maggots are feeding. It is essential that both aerobic and anaerobic tests be made. If the retarding food is used, the maggots can be kept at room or incubator temperature while the bacteriological cultures are being incubated

precaution, after the corresponding lots of maggots have been released for clinical use."

Bee venom in therapy.—Popular belief that persons habitually exposed to bee stings do not suffer from rheumatism has existed probably for centuries. Persons afflicted with rheumatic disorders commonly allow themselves to be stung by bees, hoping for relief. Mackenna [11] points out that attempts have been made to produce a stable bee-venom preparation for clinical use. These preparations are either given by transcutaneous injection or inunction. Mackenna's tests made with injections of a proprietary preparation gave encouraging results based on the treatment of over a hundred cases of "neuritis, fibrositis, rheumatoid arthritis, and osteo-arthritis."

Use of honey in the treatment of wounds.—In a valuable article

dealing with the effect of honey on bacteria and infected wounds, Gundel and Blattner [12] point out that honey has played an important rôle in the art of healing during the Middle Ages and is again gaining favor in recent times. It was early recommended for the treatment of ulcerated wounds by application of a piece of linen moistened in honey. Honey was also recommended for inflammations of the mouth cavity and throat and ulcerations of the digestive tract. Its use was also advised for the treatment of fresh and still bloody wounds by spreading honey alone upon the wound by means of a piece of cloth and then binding.

As the result of a series of tests with honey in the treatment of experimentally infected wounds in white mice, Gundel and Blattner conclude that the purposely inflicted and infected wounds treated with honey healed more rapidly than those receiving other treatments. They state that the wounds treated with honey must not be bound, and the treatment must be applied early. Based on these favorable indications, it is suggested that the therapeutic use of honey be further tested.

Gundel and Blattner also suggest the use of honey for wounds of the gums and tongue; they suggest simply taking honey into the mouth for a brief time and then swallowing it.

Mandibles of ants and beetles used in suturing wounds.—According to Gudger [13] there are numerous references in early medical literature to the use of living black ants for closing incisions and small perforations in the intestines, as well as stitching extensive wounds. These references date back to Hindoo writings as early as 1000 B.C. and probably earlier, also reference to the modern use of ants for such purposes is made in recent literature both of the Old World and the New.

It is well known that the large black ants belonging to the genus *Atta* also *Camponotus* (so-called carpenter ants) and near relatives possess powerful jaws with which they are able to grasp objects with extraordinary firmness. To effect a suture an individual ant is so placed that its jaws, which are widely open, close upon the edges of the skin and draw them snugly together. The head is then cut off, and the jaws remain firmly attached until the wound is healed. In this manner a sizable perforation may be sutured by using a number of ants.

Gudger remarks that except for India

"the use of ants for suturing among civilized people both medieval and modern [illegible] —Spain, France, Italy in former [illegible] ent days—warm regions where [illegible] oughout the greater part of the year."

Gudger also refers to the similar use of beetles belonging to the family Carabidae. The genus *Scarites* is said to have been used for stitching wounds "in Algeria, in Asiatic Turkey" and in Europe.

Xenodiagnosis.—Ashburn and Craig[14] (1907) observed that when the mosquito, *Culex fatigans* Wied., bites, it manages to get from the body of the patient 40 to 50 or more times as many filariae as it is possible to obtain in a similar amount of blood from a needle prick. They point out that this fact might have a practical value in examining cases of suspected filariasis in which the parasites are so few in number as readily to be missed.

In 1914 Brumpt[15] coined the term *xenodiagnosis* to designate the use of uninfected reduviid bugs (*Triatoma*) in the diagnosis of Chagas' disease.

Hinman[16] conducted experiments with an alcoholic extract of the salivary glands of mosquitoes, *Culex fatigans* Wied., to test a possible chemotactic reaction of the dog filaria, *Dirofilaria immitis.* Tests were made on infected dogs by first counting the number of microfilariae in a known quantity of the dog's blood (0.01 cc. usually), immediately following this an injection of 0.1 cc of the salivary extract was made, and after a period of one to two minutes another sample of blood was taken from the site of the injection. Hinman reports the results of this research as rather "inconclusive."

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